
TESTS OF CLAY PRODUCTS

BY

A. MARSTON.

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CHAPTER VIII.

Tests of Dry Press Building Brick Commonly Used in Iowa.

INTRODUCTION.

The series of tests described in this paper was undertaken with two aims in view. First, to determine the relative qualities of the dry press building brick commonly in use in this state, especially with a view to determine whether or not the home made brick were equal to those imported from adjoining states; second, to determine in the course of the tests various points of scientific interest in connection with the proper methods of testing dry press building brick.

As regards the first of the above objects it may be said that in the diagrams accompanying this paper the relative rank of the different kinds of brick may be readily seen. On these diagrams the different kinds of brick are indicated by letters for the sake of simplicity. The key to the kinds is given in the following table:

KEY TO KINDS OF BRICK.

Letter.	KIND.	Letter	KIND.
A	Van Meter Red.	a	Van Meter "d" Red.
B	Van Meter Buff.	b	La Salle No. 2 Buff.
C	La Salle Buff.	c	La Salle No. 1. Mottled.
D	Corey "a" Red.	d	St. Louis 7 Red.
E	Omaha 10 Red.	e	Corey 20 red.
F	Dale Goodwin Buff "P".	f	Corey "f" Buff.
G	St. Louis 100 Red Granite.	g	Corey 16 Red.
H	St. Louis 500 Mottled Gray.	h	St. Louis 500 Steel Gray.
I	La Salle 1 Red.	i	La Salle No. 2 Mottled.
J	Corey 7 and 9 Buff.	j	St. Louis 509 Red Granite.
K	Omaha 555 Buff.	k	Omaha 575 Gray.
L	Dale Goodwin Buff "B".	l	Omaha 550 Light Mottled.
M	Gethmann No. 10 Red.	m	St. Louis 511 Light Buff.
N	Gladbrook No. 1 Red.	n	Omaha 550 Dark Mottled.
O	Gethmann No. 6 Red.	o	Omaha 5 Red.
P	Gladbrook No. 3 Red.	p	Gladbrook No. 6 Red.

The capital letters refer to those kinds in which cubes were frozen and thawed 40 times, while the small letters refer to those frozen and thawed 20 times.

In figure 89 the bricks are ranked in the order of their transverse strength. While the rank would vary with the different tests yet it will be seen that brick A, the Van Meter Red, ranked highest in all of the tests. This speaks well for Iowa brick. Brick B, the Van Meter Buff, ranks next. This brick makes a beautiful material for building purposes. It has been used for the construction of the Chimes Tower of the Iowa State College at Ames, Iowa, and in this structure has stood the test of several years exposure to the elements. The tower remains as beautiful as it was when first erected and stands as a monument to the good quality of Iowa pressed brick.

Bricks D, e and g, Corey Red manufactured at Lehigh, Iowa, and bricks J and f, the Corey Buff manufactured at the same place, are also most excellent brick manufactured in Iowa. Together with the Van Meter Buff the Corey Buff brick have been used for the interior finish of the walls of the new Engineering

Hall at Ames, which by many competent persons, has been pronounced the finest building of its kind in the country. The use of buff, dry pressed brick for the interior finish of churches and other public buildings is becoming deservedly popular. It makes a finish which, unlike plaster, is permanent as well as pleasing. If the walls should become stained with dirt they can be cleaned without the necessity of putting on a fresh coat of plaster, kalsomine or paint.

Bricks F and L, Dale Goodwin Buff, manufactured at Grand Junction, and bricks M, N, O, P and p, all red pressed brick manufactured at Gladbrook, Iowa, by the Gladbrook Pressed Brick Company and by Gethmann Brothers, are also excellent dry pressed brick.

This series of tests has thoroughly demonstrated that in quality Iowa dry pressed brick can compete with any manufactured in the country. Where the Iowa plants are lacking at present is, first, in their facilities for making brick in sufficient quantities so that architects and contractors can rely upon their being obtained without undue delay; and second, in their facilities for supplying different architectural grades of brick. Both of these deficiencies are of such nature as to be readily supplied by Iowa manufacturers. The question of quantity is one simply of a plant large enough for carrying on the work. The writer has had unfortunate experiences in getting Iowa dry pressed brick in quantities sufficient to enable the rapid carrying on of work in which he has specified their use. The quality of the brick is such that if well advertised and exploited there should be no trouble in disposing of the products of large plants.

The question of different architectural grades of brick is one for experimentation with different qualities of material and with the substances commonly used to produce the different colors and surfaces needed for architectural appearances. It is now possible to have samples of clay sent to the Ceramic Lab-

oratory at Ames, and there tested to determine what can be attained along these lines. There is no doubt that any enterprising manufacturer of good dry press brick could develop a sufficient number of kinds of brick to meet all necessities.

Incidentally, by the way, the query may be propounded, why do not the manufacturers of dry pressed brick in Iowa turn out to the meetings of the Brick and Tile Association, and display a public interest in the advancement of this industry? In the procuring of the specimens for these tests more trouble was experienced with one of the Iowa manufacturers than with all of the companies outside of the state. It is difficult to understand why this should be so when the tests were carried on without expense to the manufacturers and were planned mainly for their benefit.

It is to the second of the purposes for which these experiments were planned that this discussion will be mainly confined. To indicate what degree of reliability may be given to the conclusions reached, the number of tests may be stated; in all about 800 transverse tests were made; 100 crushing tests; 128 specific gravity determinations; 128 freezing and thawing tests. In all some 32 grades of dry press building brick from eight different companies were thoroughly tested, and several grades were partially tested. In testing each grade of brick twenty or more transverse tests were first made. From the ends of these broken brick cubes were then prepared for the crushing, absorption, specific gravity, and freezing and thawing tests.

The transverse tests were carried out in the manner adopted as standard by the Department of Civil Engineering of the Iowa State College for making such tests. Knife edges six inches apart, rounded both ways, were used to support the brick which were placed on edge in the machine. An adjustable knife edge was used at the top to apply the load mid-way be-

tween the supports. Steel bearing blocks were used between all knife edges and the brick to keep the knife edges from cutting into the brick and causing failure from local injury.

The crushing tests were partially made on two-inch cubes with two smooth surfaces at top and bottom, the bearing surfaces of the testing machine being steel plates. Other tests from the same brick were made upon specimens of larger size, each about one-third of a brick placed flatwise in the machine, and bedded above and below with plaster of Paris. The absorption, specific gravity, and thawing and freezing tests were all made upon four different kinds of cubes for each grade tested. For each grade two-inch and one-inch cubes ground truly to shape and size were tested, and also two-inch and one-inch cubes simply chipped out approximately to shape and size, but with surfaces left rough.

Compression Tests.—In fig. 82, the results of the compression tests are shown, and it will be noted that the tests of two-inch cubes with steel bearing plates showed considerable higher re-

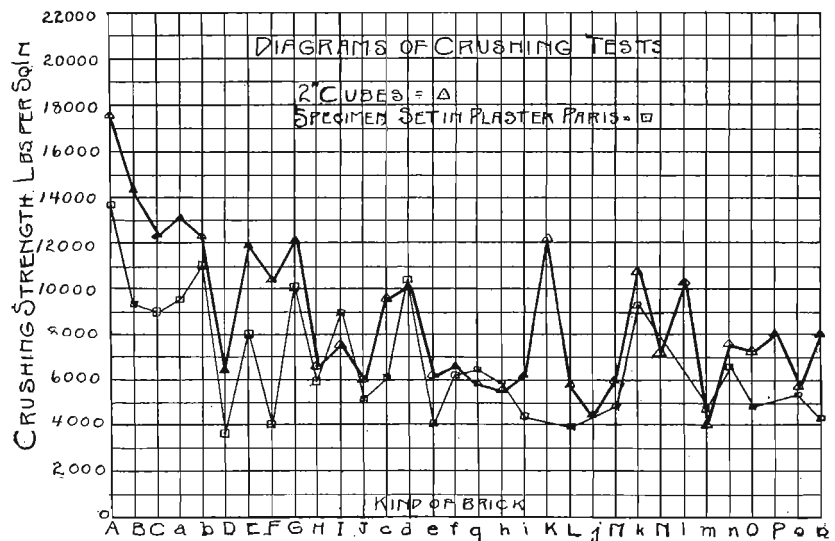


FIG. 82. Diagram showing results of compression tests.

sults than the tests of specimens set in plaster of Paris. For standard tests the writer is of the opinion that the specimens should be ground to two-inch cubes and steel bearing surfaces used.

Transverse Tests.—In fig. 83 four typical transverse tests were platted in detail. The transverse tests for the other grades would show similar results. The point brought out specially in these diagrams is the great lack of uniformity of the different individual specimens of the brick tested. Practical brick-makers are thoroughly aware that in each kiln of brick they make, all qualities of brick are found, from those too soft to use for any purpose, to those which are the best that they can turn out, and still further to those that are so over-burned as to be of no value for building purposes. Engineers and architects, however, in their specifications and in their modes of

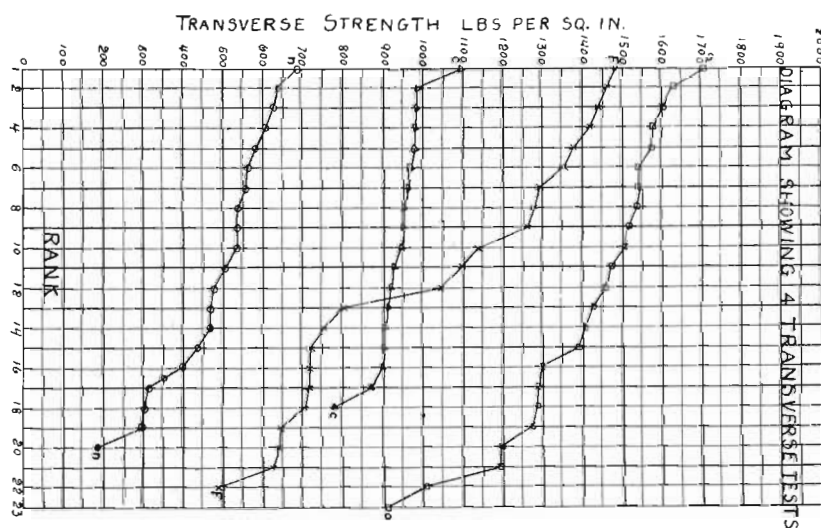


FIG. 83. Diagram showing results of transverse tests.

testing, seem to have overlooked, or not to have understood, this fact. Where the lack of uniformity is so great as is indicated by these transverse tests, it is evidently useless to try to rank

brick by tests of only a few from each grade, yet that is what is commonly attempted. It is often urged against transverse tests that they fail to give uniform results, but as the outcome of having personally seen to the carrying out of thousands of transverse tests the writer wishes emphatically to express his opinion that the transverse tests truly indicate the facts regarding the structure of the brick. They are to be commended, instead of condemned, because they bring out these facts. The writer has carried on such tests by the hundred, making comparison of the structure of each brick with the results of the transverse tests, and he is firmly convinced of the value of the transverse tests as indicating the quality of the brick. One of the most valuable characteristics of transverse tests is the facility with which they are made. On account of this facility a large number can be carried out for each grade of brick tested, and the average will give results correspondingly more reliable than those of a small number of brick.

The other tests also gave widely varying results when made upon different specimens of the same grade of brick. This is to be carefully borne in mind whenever an attempt is made to compare the ranking of different grades of brick by the results of the different tests, and it explains the most of the discrepancies which are usually noted.

Absorption Tests.—In figs. 84 and 85, the final results of the absorption tests for the different grades of brick are shown. In carrying out the absorption tests the specimens were first dried in an oven until they showed no further loss of weight from evaporation, and were then completely immersed in water and weighed at intervals. All the specimens showed a rapid absorption of water within the first three or four hours, and after the first twenty-four hours they showed a small, but still quite appreciable, increase in absorption. The specimens were left immersed about ten days, and at the end of the experiments

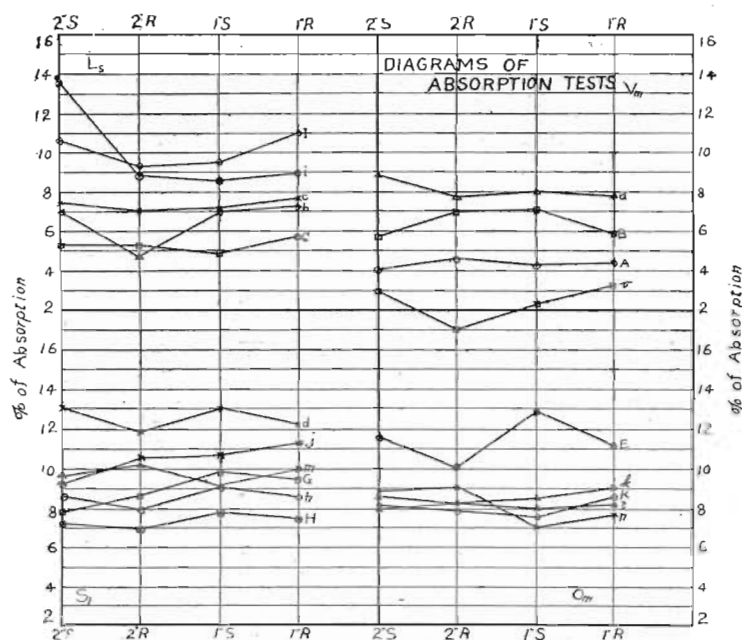


FIG. 84. Diagram showing results of absorption tests.

they were still absorbing water, so that the results given cannot be taken as the final per cents which they would take up. In figs. 84 and 85, the results of the different cubes are indicated by the figures and letters. 2" S indicates the two-inch smooth cube; 2" R indicates the two-inch rough cube, and the one-inch smooth and the one-inch rough cubes are indicated in similar ways. A careful study of the diagrams will show that there is no very great difference in the results with the different specimens. On the whole, however, the smaller cubes give slightly greater per cents than the larger cubes.

Freezing and Thawing Tests.—In figs. 86 and 87, the results of the freezing and thawing tests are indicated in a similar manner. These freezing and thawing tests were made upon the specimens saturated for the absorption tests. These were put into a freezing box, in which a temperature of from zero to six

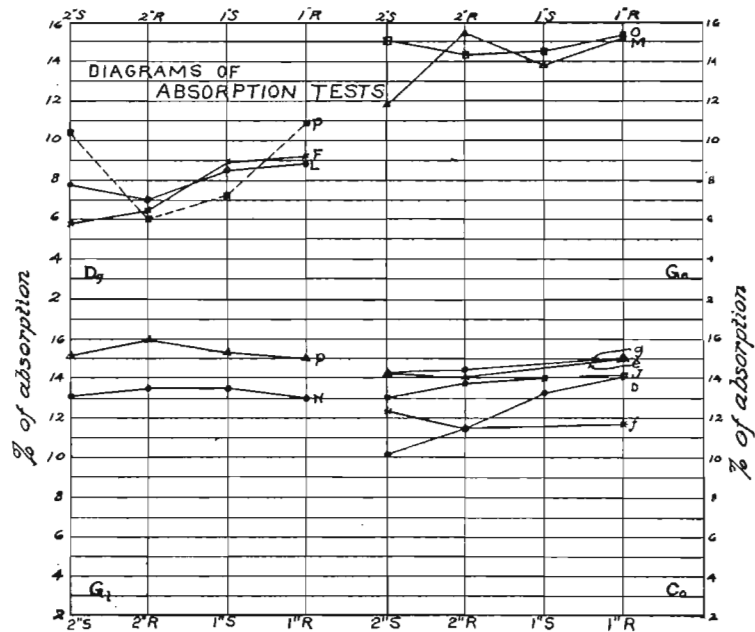


FIG. 85. Diagram showing per cent of absorption of brick tested.

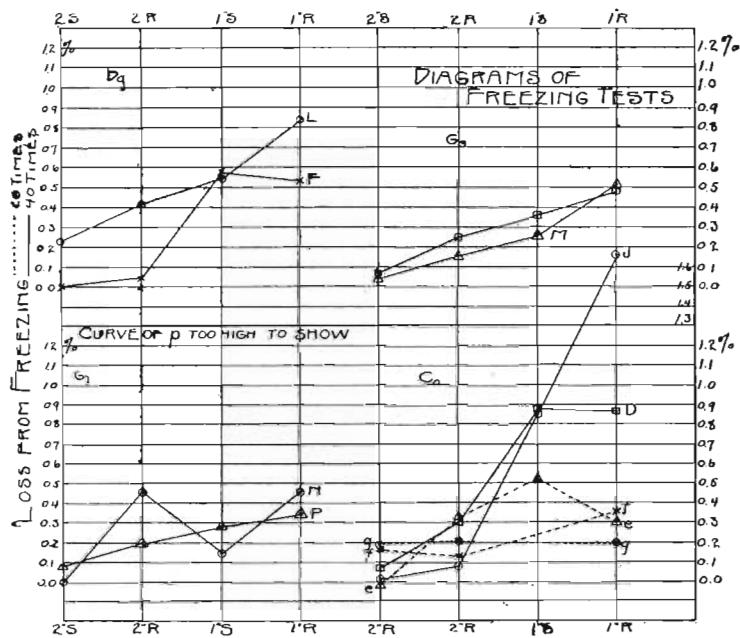


FIG. 86. Diagram showing results of freezing tests.

degrees above zero F. was maintained by a mixture of salt and ice. During the first twenty freezings and thawings the specimens were first frozen forty-eight hours, and then thawed by immersing in water for twenty-four hours. After the first twenty tests, the time of freezing was reduced to twenty-four hours, as the temperature records indicated that the cubes were completely frozen in that time. The writer advocates the twenty-four hour period as standard for such tests. The results of the tests show clearly that the rough cubes give greater losses than the smooth cubes, and that the small cubes give

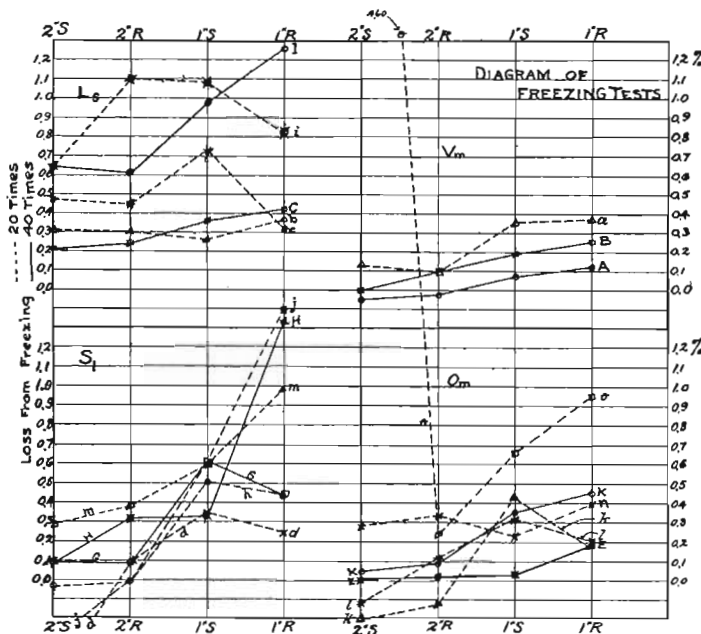
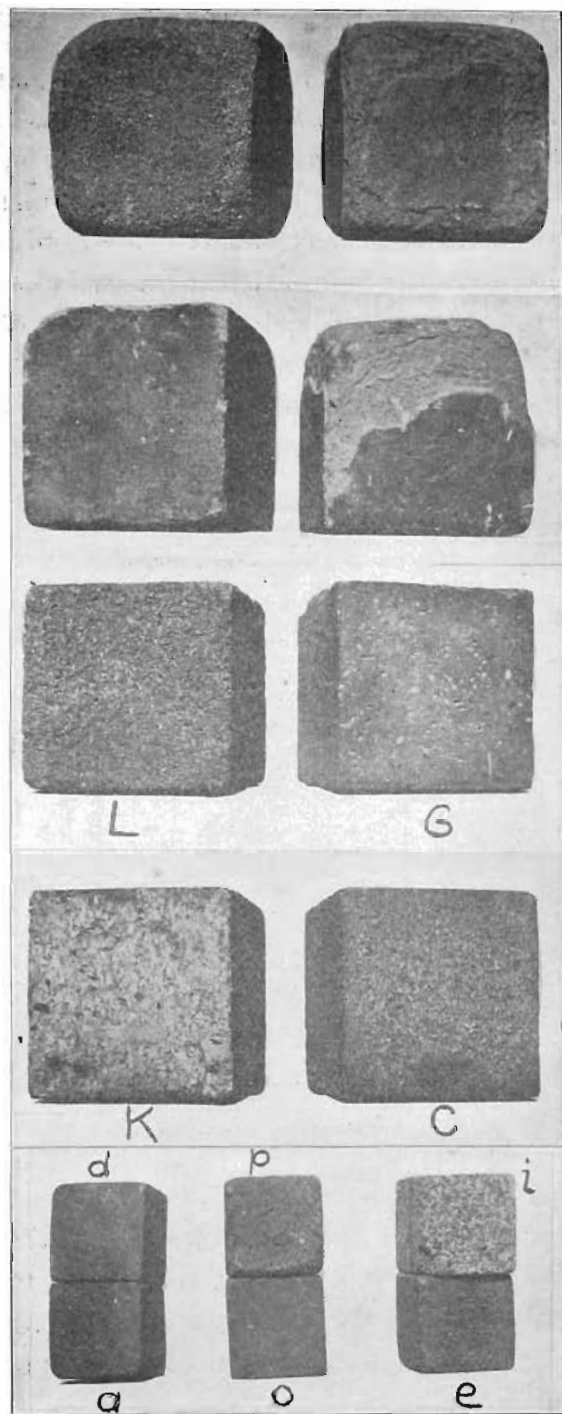


FIG. 87. Diagram showing comparative loss on a varying number of freezings.

greater losses than the large cubes. The writer advocates as standard for freezing and thawing tests one-inch smooth cubes. The rough cubes would give higher losses, but the smooth surface of the one-inch cubes enables the disintegration to be seen more clearly by the naked eye or under the microscope than is possible with the rough cubes.



LAKE
SUPERIOR
SAND-
STONES

FROZEN 20 TIMES

BEREA
SAND-
STONE
ON LEFT

LEGRAND
LIME-
STONE
ON RIGHT

FROZEN 40 TIMES

SPECI-
MENS OF
DRY
PRESS
BUILDING
BRICK

FROZEN 20 TIMES

PLATE XXXVIII.

In plate XXXVIII some photographs of the smooth cubes subjected to the freezing and thawing tests are given. The four cubes at the top of the figure represent tests of some commonly used building stones, and are shown here for comparative purposes. These were two-inch cubes and were frozen and thawed twenty times. It will be seen that the effects were very marked. In other tests of commonly used building stones some cubes show very little effect, while in one case a cube of Joliet stone was entirely destroyed. Buff Bedford stone showed about the same effect as the cube of Berea sandstone. Blue Bedford stone was apparently unaffected, as were also some cubes of Anamosa stone and the best grades of LeGrand stone. The four two-inch cubes shown immediately below the four cubes of building stone represent freezing and thawing tests made forty times upon specimens of the dry press brick. It will be seen that double the number of exposures produced much less effect than in the tests of the building stone, and, in general, it may be said that the tests on the best grades of dry press brick compare very favorably indeed with the tests of our best building stones. In the lower part of plate XXXVIII are shown the results of twenty freezing and thawing tests of six one-inch cubes of dry press brick. The cubes shown in plate XXXVIII may be taken as representative of the results of the tests of the dry press brick.

In the climate of Iowa the freezing and thawing test is the only direct one which can be applied to building brick, to duplicate the conditions under which they fail in actual use. A close observer will readily find many instances in any Iowa town in which the ordinary building brick show serious evidences of disintegration from freezing and thawing. These effects are especially to be looked for near the ground and directly under the coping. The only objection to the freezing and thawing test for building brick is the great expense and large amount of time required to carry it out. To freeze and thaw brick forty times in the manner followed in these tests would require eighty

days of continuous test, and unless a large number could be carried through at a time the expense per test would be great.

Since these tests were completed, however, as a result of further experimenting it has been found possible to reduce the time required by one-half, by freezing one-inch cubes twenty hours each day and thawing them four hours in hot water. This method is now adopted as standard in the writer's laboratory. The use of one-inch cubes enables a very large number of specimens to be treated at one time and the result is to greatly cheapen and simplify the freezing and thawing test.

The transverse test of brick is the one most readily and cheaply made, and as it detects all hidden flaws and enables a close study to be made of the internal structure of the brick, it is of great value, although to be considered simply as an indirect test. Close observation in carrying out such tests has shown the writer that the finer grained, more uniform and dense the structure of the brick, the higher will be the transverse strength; and also, the better burned the brick is the greater will be its transverse strength. We may hence consider it to be a fair measure of the quality of the brick for ordinary purposes, and it is of especial value because it can readily be made on a large number of specimens. To indicate how well the results of transverse tests conform to the results of freezing and thawing tests, fig. 88 is given. In this figure the brick tested have been grouped in the order of their rank, as shown by the transverse tests, and the results of the freezing and thawing tests are platted on the same diagram. It will be seen that there is a general agreement between the tests, although there are wide variations from the general rule. These variations are largely to be explained, the writer thinks, by the fact that the freezing and thawing tests were made on a very small number of brick from each grade, sometimes not more than two, while the

transverse tests give the average in each case of more than twenty brick. The results of the freezing and thawing tests also are to be taken as comparative rather than absolute, because in the work of the testing some brine came in contact with the brick, and it is certain that not quite all of the salt absorbed was gotten rid of before the weighings. This fact will explain some apparent discrepancies in figs. 86 and 87.

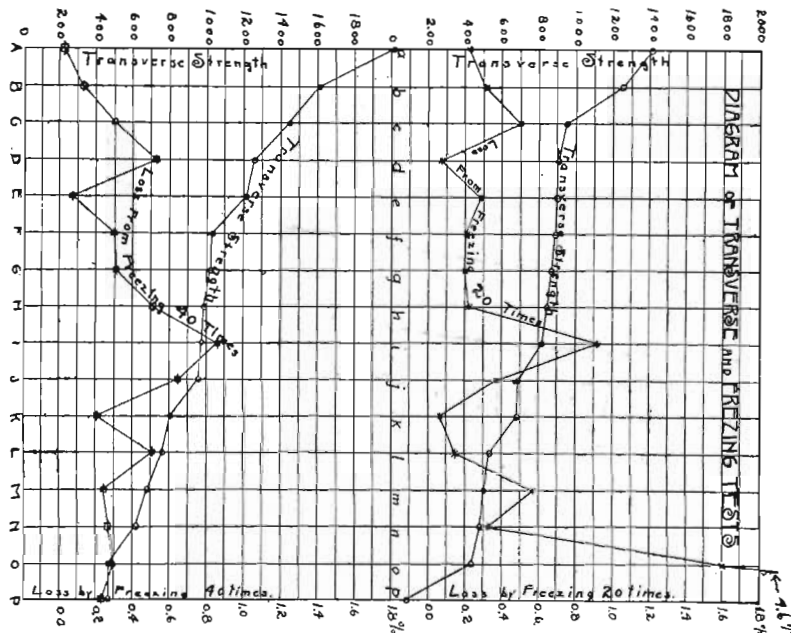


FIG. 88. Diagram showing results of transverse and freezing tests.

COMPARISON OF THE ABOVE TESTS.

To enable the comparison to be made between the results of all the different tests made on these brick, fig. 89 has been constructed. In this figure also the brick are ranked according to the results of the transverse tests, as all the other tests were made on a comparatively small number of specimens. It will be seen that there is a general agreement between the results of the different tests, with many discrepancies, however. These discrepancies are largely to be explained from the great lack

of uniformity which, as has already been shown, exists between different individual specimens of the same grade of brick, and from the fact that in all but the transverse tests only a small number of specimens were tested. The general agreement of the different tests is most readily seen by comparing the best grade with the poorest. In this case the same grade of brick

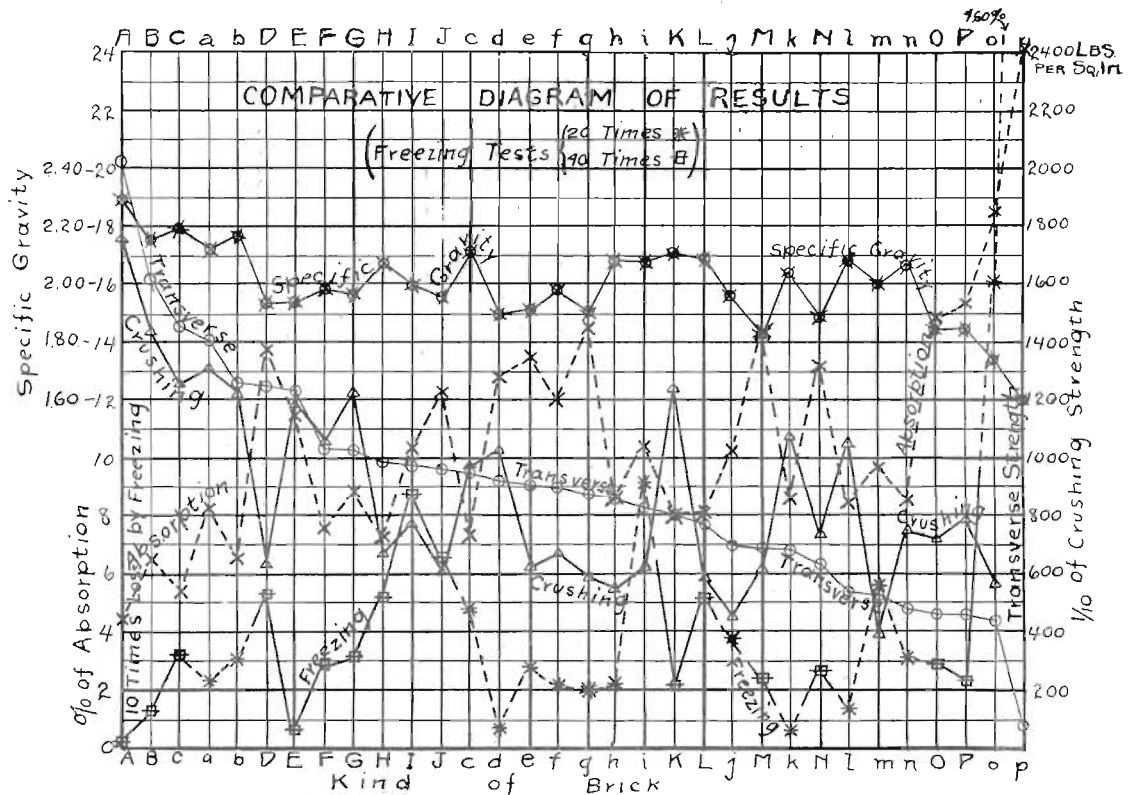


FIG. 89. Diagram showing comparative results of the different tests.

which gave the highest transverse strength had also the highest crushing strength, the lowest per cent of absorption, the smallest loss from freezing and thawing, and the highest specific gravity; while the brick which showed the lowest transverse strength was poorest in all the other tests which were made upon it. This poorest brick was one too soft to rank as

anything but an ordinary building brick, and was sent by special request made to the makers. It would probably be a better brick, however, than most of the ordinary sand brick used for building purposes in Iowa.

SUMMARY OF TESTS.

It would seem advisable to recapitulate the principal conclusions brought out by the discussion of this series of tests, as follows:

First. The best brick tested was an Iowa brick, and there appears to be no reason why the very best quality of dry press brick should not be made in Iowa.

Second. There is a great lack of uniformity in different brick from the same grade and the same kiln, and a large number of tests should be made to secure reliable deductions as to the relative rank of different grades of brick. The writer may add in this connection that in his opinion the making and interpretation of such tests should be intrusted only to experts who are perfectly familiar with the actual processes of the manufacture of brick.

Third. Crushing tests should be made upon two-inch cubes, with steel bearing plates.

Fourth. The size and character of the surface of the specimen make little difference in the results of absorption tests within the range of one-inch to two-inch cubes. Ten days immersion does not give complete saturation.

Fifth. One-inch smooth cubes should be adopted as standard for absorption and for freezing and thawing tests. These cubes should first be immersed in water and weighed, first at very short intervals, and then at longer intervals, until they are practically saturated. They should then be placed in a freezing box, in which the temperature should be 0 to 6° F. constantly maintained. This temperature can readily be attained

by the use of salt and ice. The cubes should be frozen twenty hours each day and thawed four hours in hot water having a temperature of about 150° F.

Sixth. The transverse test is one of the most valuable tests which can be made on brick. In carrying it out the brick should be placed on edge on knife edges six inches apart, rounded both ways, as for standard tests of paving brick. The pressure should be applied by a knife edge adjustable or rounded both ways, the steel bearing plates should be used between all knife edges and the surfaces of the brick. The brick should not be ground or prepared in any way for the transverse test. Careful study should be made of the internal structure of each brick in comparison with the results of the test upon it.

In conclusion the writer desires to say that the greater part of this series of tests was made by Messrs. George A. Smith, B. C. E., and F. I. Nichols, B. C. E., graduates of the Department of Civil Engineering of the Iowa State College, as thesis work. It is their earnest and painstaking work which has enabled the tests to be made.

Tests of Iowa Common Brick.

INTRODUCTION.

The following tests of common brick were carried out by the civil engineering department of the Iowa State college during the year 1902. The tests were undertaken as thesis work by Messrs. J. F. McBirney and J. E. Stewart, two senior students, who did most of the testing and calculating, and platted many of the curves. The writer desires to call especial attention to their painstaking work, and to say that without such invaluable assistance from students, given without remuneration in money, the investigations of Iowa brick heretofore reported by him, as

well as those now to be discussed, could not have been undertaken.

Previous tests of Iowa brick have been made of pavers and of dry press brick. The following tests are the first in which many data of the properties of common brick in this state have been ascertained. The greater part of the brick manufactured in the state are common brick and there is room for great improvement in the methods of manufacture. It should be understood by manufacturers and users of such brick that the testing of the product is one of the best means to bring about these improvements.

MANNER OF TESTING.

The brick were tested in four ways: viz., for transverse strength, crushing strength, percentage of absorption, and resistance to freezing and thawing. The transverse tests were made upon brick placed flatwise, on knife edges six inches apart, the knife edges being rounded both ways. Steel bearing blocks 3-4" x 3-4", a little less in length than the width of the brick, and with rounded edges, were placed between the knife edges and the brick. The crushing tests were made between adjustable steel plates, on two-inch cubes, ground out by an emery wheel. The absorption tests were made on one-inch cubes, immersed in water and weighed at intervals up to two or more weeks, but the brick are compared on the basis of forty-eight hours immersion. On the completion of the absorption tests the freezing tests were made by placing the saturated one-inch cubes in a freezing box where they were subjected to a minimum temperature of about one or two degrees above zero Fahrenheit, for twenty-four hours; then thawed in water twenty-four hours, then re-frozen twenty-four hours, etc., until the cubes were demolished.

Twenty-five bricks of each kind were broken in the transverse test. From the broken ends of ten of these the cubes were prepared for the other tests. Another set of transverse tests with the brick placed on edge was also made. In all six hundred and twenty-six transverse tests and one hundred and thirty each of crushing, absorption and freezing tests were made.

BRICK TESTED.

The brick tested were the product of seven different Iowa brick plants: viz., L. C. Besley, Council Bluffs; The Webster City Brick and Tile Company; The Dale Brick Company, Des Moines; the Goodwin Tile and Brick Company, of Grand Junction; the Mason City Brick and Tile Company, of Mason City;

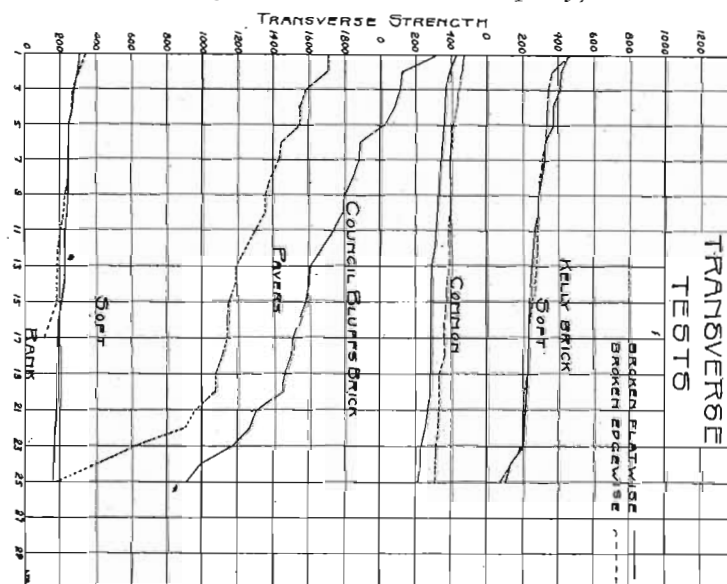


FIG. 90. Transverse tests, Council Bluffs brick.

the Kelly Brick and Tile Company, and the yard formerly operated by Mr. Cameron just west of the college. The following brief description of the clays and the processes of manufacture used in these different establishments has been prepared by Prof. S. W. Beyer.

Besley Brick.—All brick in and about Council Bluffs are made from loess clays or modified loess in the form of wash from the adjoining bluffs. Mechanical analyses show that fine sand and silt predominate with a lesser quantity of clay substance. Practically the entire mass will pass through a 100-mesh sieve. A small percentage of lime is usually present in a finely divided state and occasionally in the form of concretions and molluscan shells. Other deleterious elements are rarely present.

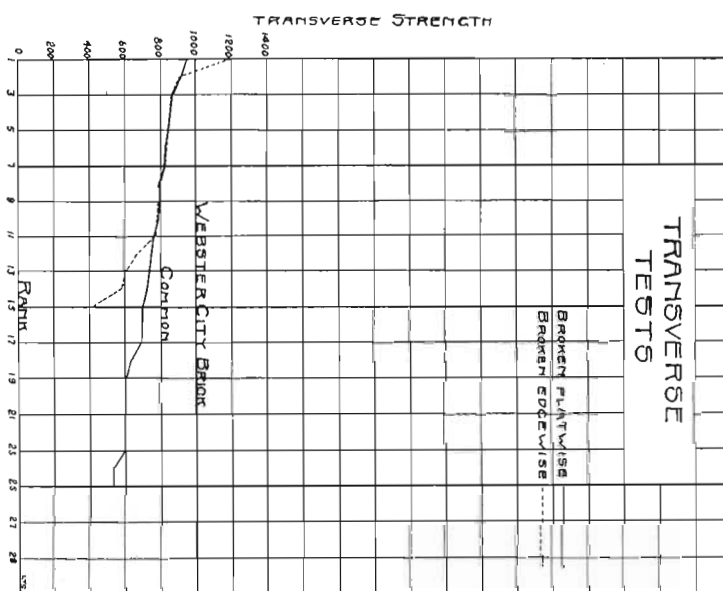


FIG. 91. Transverse tests, Webster City brick.

Webster City Brick.—Averages about one part shale obtained from the Des Moines stage of the Coal Measures to two parts surface wash and alluvium. The shale is variable in color, fissile and fairly plastic. The surface material contains a high percentage of fine sand and silt with but little clay substance, and some lime in a finely divided state.

Dale Brick (Des Moines).—The raw material is ordinary alluvium mixed with wash and loess. Sand and silt constitute the larger portion with a smaller balance of clay substance. No deleterious elements are present.

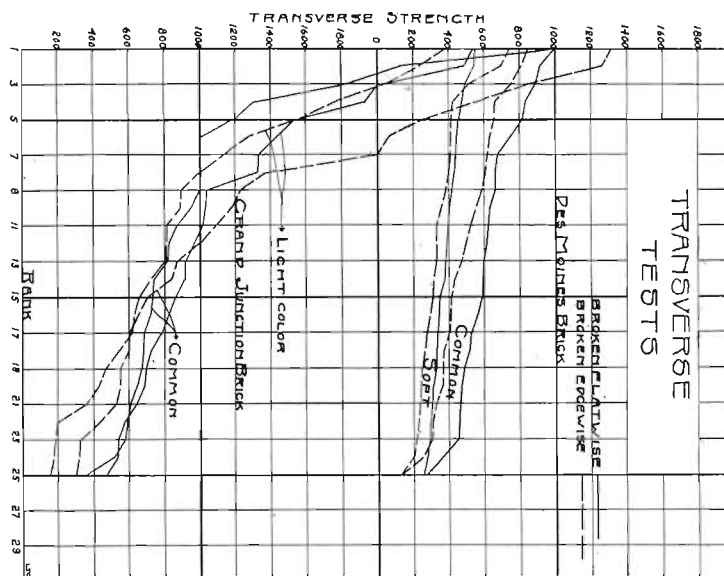


FIG. 92. Transverse tests, Des Moines brick.

Grand Junction Brick.—The raw material consists of a mixture of shale and fire clay and belongs to the Des Moines stage of the Coal Measures. The shale is slightly pyritic and moderately fissile and works into a plastic mass. The fire clay is plastic and non-fissile and more or less leached of the fluxes. The green brick is a heterogeneous mixture of the two.

Mason City Brick.—The material used is a shale clay belonging to the Line Creek stage of the Devonian. The unaltered clay is blue-gray in color, exceedingly fine-grained, highly plastic, and but imperfectly jointed, and slightly fissile. The irregular joints often contain gypsum cleavage flakes and crystals. Iron pyrite grains irregularly distributed and with the gypsum form the only grit which can be detected throughout the beds.

The upper portion of the clay beds are somewhat iron-stained to varying shades of yellow and brown, the stains following the jointings down to a considerable depth. Line in a finely divided state is present throughout the deposit.

Ames and Kelly Brick.—The material is practically the same and belongs to the loess. The beds used in each case have been

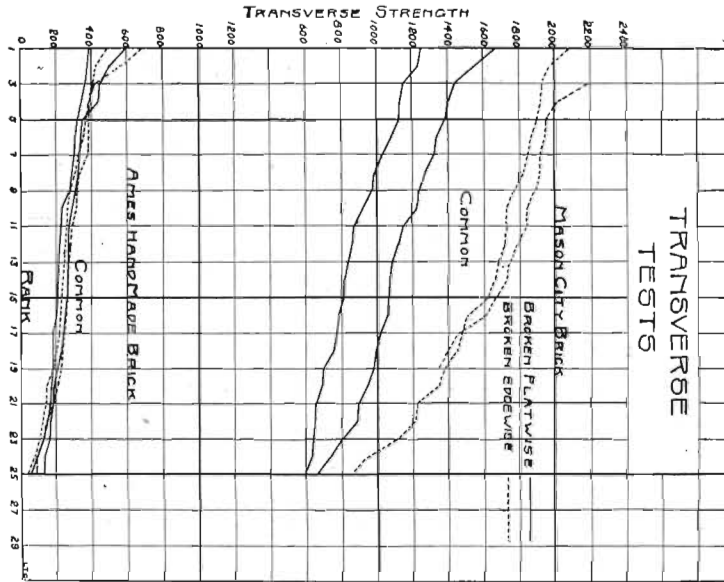


FIG. 93. Transverse tests, Mason City brick.

covered by the Wisconsin drift which necessitates considerable stripping. The loess clay at these places contains less fine sand and silt and more clay than does the Missouri river loess. It also contains more lime, both disseminated and in the form of concretions, and occasionally contains iron pyrite. Here, as is usual with loess deposits, the beds run sandier below and as in all loess clays the green ware is very tender and requires careful handling.

STRUCTURE OF BRICK TESTED.

Regarding the structure of the brick it may be said that the Council Bluffs brick were soft mud, machine made brick and were very fine-grained and homogeneous in texture, and free from laminations, the only noteworthy irregularity being the poor structure of the under side of the brick in the molds of the soft mud machine. Two grades were shipped by Mr. Besley for the tests, one grade consisting of very hard burned brick,

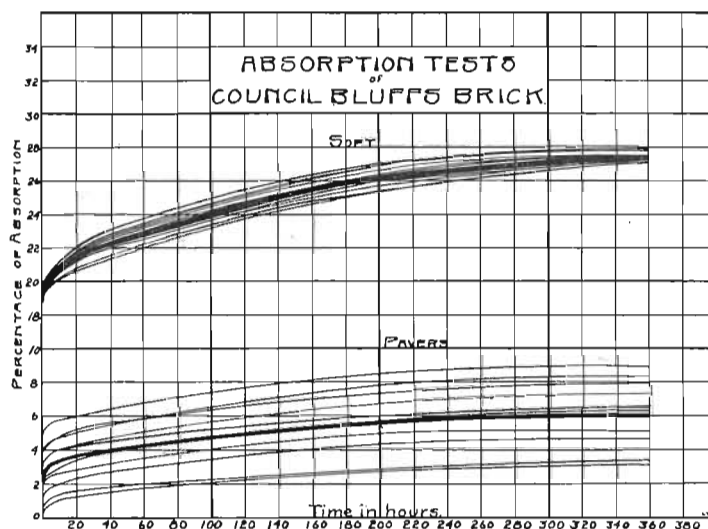


FIG. 94. Absorption tests, Council Bluffs brick.

good enough for pavers, while the other grade was composed of soft, under burned brick.

Only one grade of Webster City brick was tested and this consisted of heavy and uniformly well burned, stiff mud, side cut, brick. The interior structure showed a mixture of materials, which gave a rather loose appearing texture, but the mixture was quite uniform, the color indicated thorough burning, and the weight indicated that the porosity could not be great and the brick were hard.

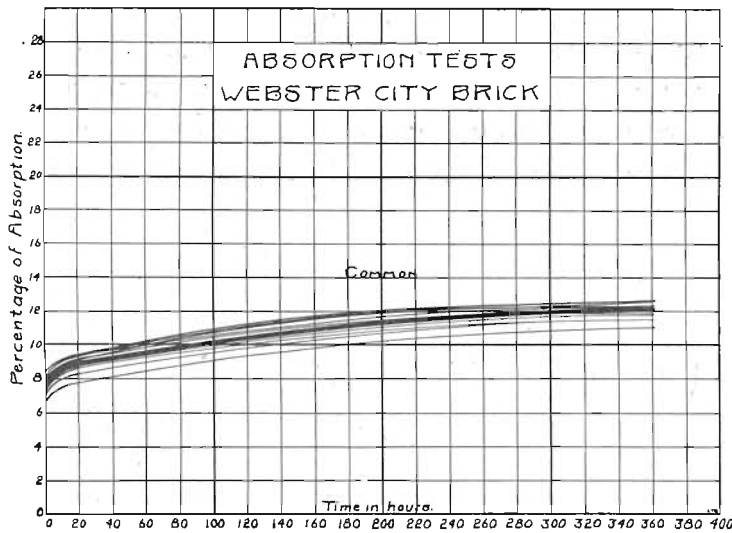


FIG. 95. Absorption tests, Webster City brick.

The Dale brick from Des Moines were selected as fairly representative of several cars shipped for the backing of the walls of the new Engineering Hall of the Iowa State College. All were stiff mud, side cut brick. Those hereinafter designated "com-

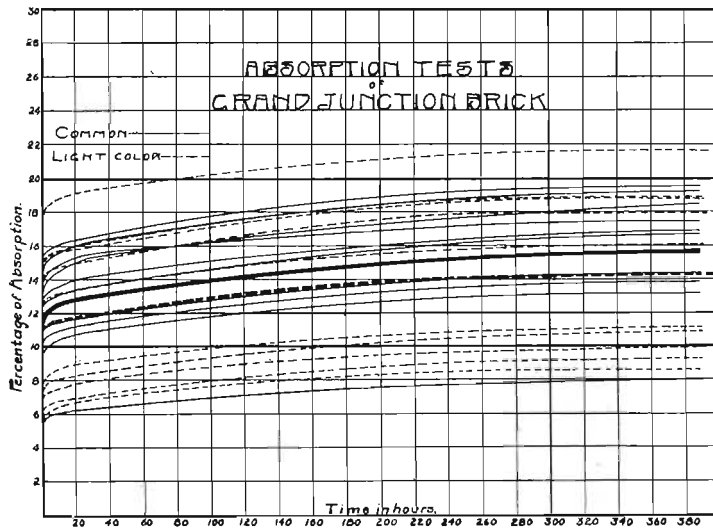


FIG. 96. Absorption tests, Grand Junction brick.

mon" were quite well burned, and of a uniformly red color, and of fairly uniform structure, although not so heavy and hard as the Webster City brick. Those Dale brick hereinafter designated "soft," were like the others except for being under burned, and in fact too soft for any use except the interior filling of walls.

The Grand Junction brick were also selected as fairly representative of some shipments for the backing of the walls of the

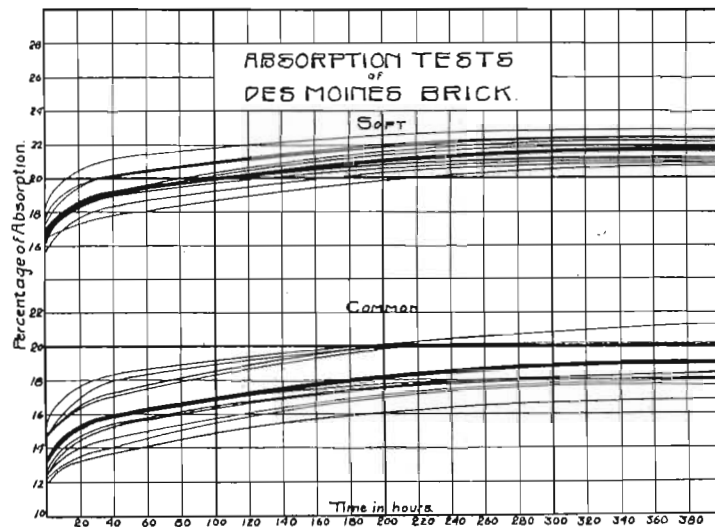


FIG. 97. Absorption tests, Des Moines brick.

Engineering Hall, and were also stiff mud, side cut brick. They were small but heavy for their size, and were made of a clay which burns to a light color, so that the lighter colored brick are the harder. The color in broken sections was quite irregular, some specimens, for example, showing a light colored external layer, then a reddish layer, and then a dark colored, blue or drab core. The color varied greatly with the different brick, however. The brick were small but heavy for their size, and quite hard. They showed some lamination. Two sets of tests

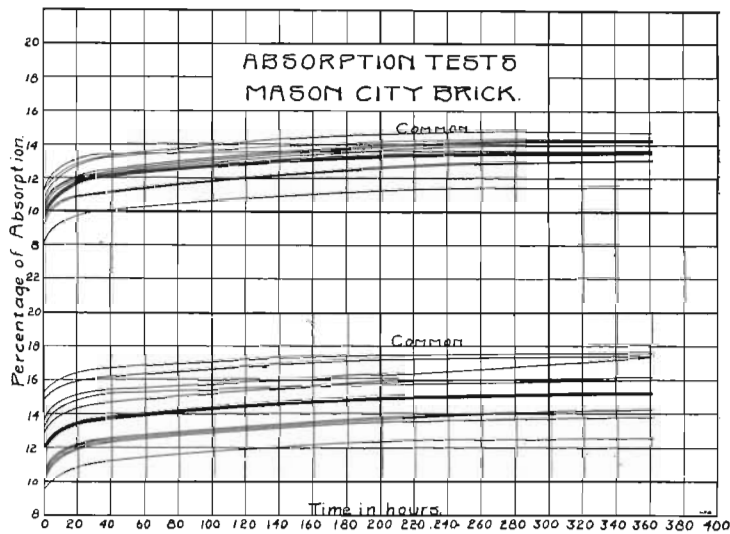


FIG. 98. Absorption tests, Mason City brick.

were made of these brick. The specimens of the two sets were not widely different in character, though probably the set marked light colored were on the average a little better burned.

The Mason City brick were stiff mud, side cut brick, hard,

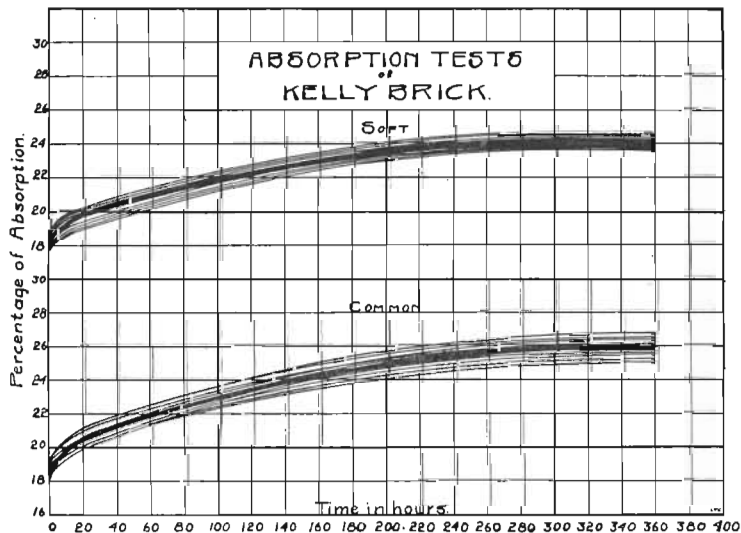


FIG. 99. Absorption tests, Kelly brick.

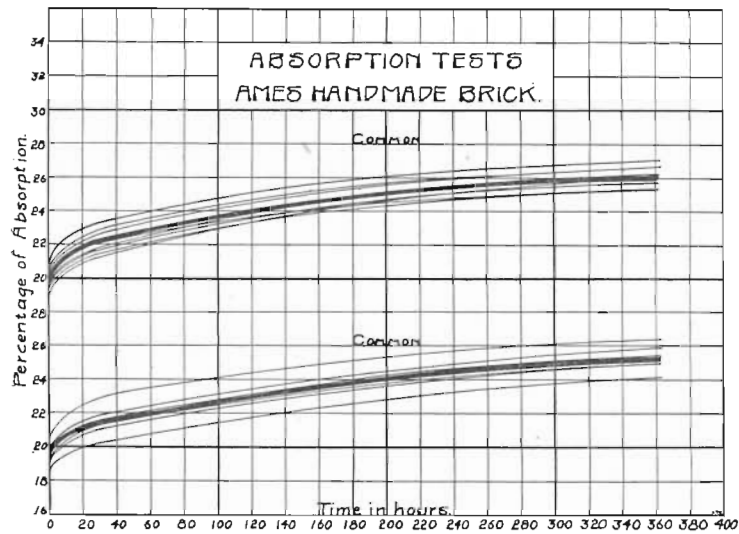


FIG. 100. Absorption tests, Ames hand made brick.

strong, heavy and moderately well burned. It was intended to test two grades, but when the brick arrived no very great difference could be detected, and the two sets of tests were on about the same grade of brick. These brick have a rather peculiar

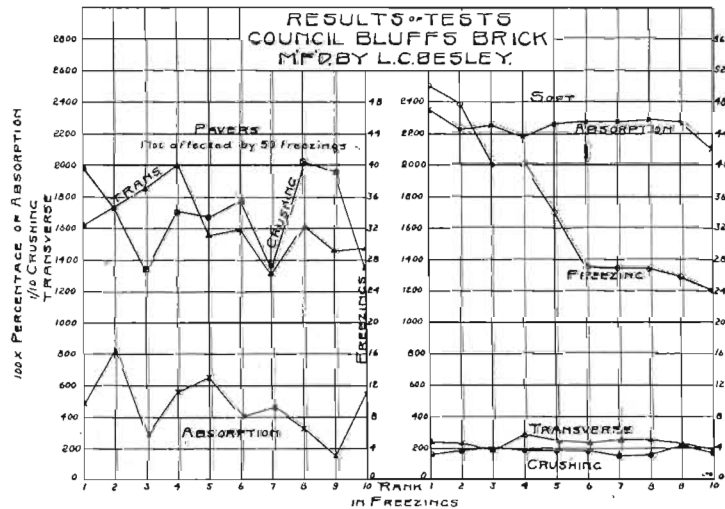


FIG. 101. Comprehensive diagram of results of tests on Council Bluffs brick.

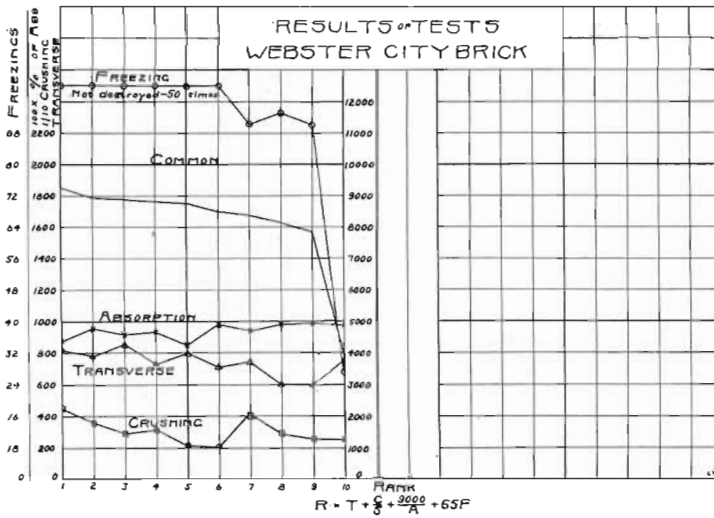


FIG. 102. Results of tests, Webster City brick.

structure. The material is evidently hard, strong, and durable, but the interior of the brick is badly laminated or fissured, up to within a short distance of those sides and ends which bear against the die in the machine. All surfaces of the brick which would be exposed in a wall, therefore, have an external layer of

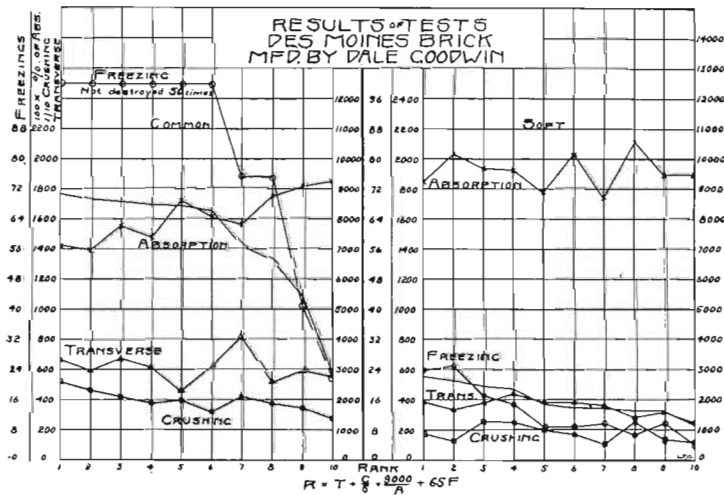


FIG. 103. Freezing tests, Goodwin brick.

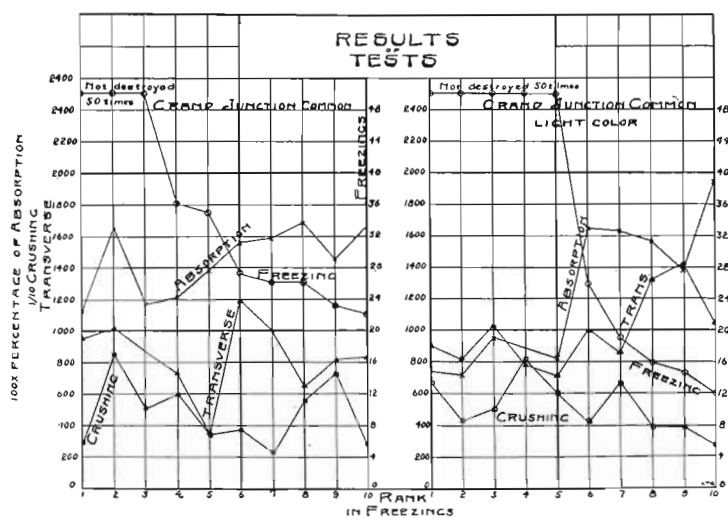


FIG. 104. Comprehensive diagram, Grand Junction brick.

extra good material. The brick were fine-grained and fairly homogeneous. The common quite frequently contained nodules of caustic lime, and the soft also contained a few such nodules, but not so many as the common.

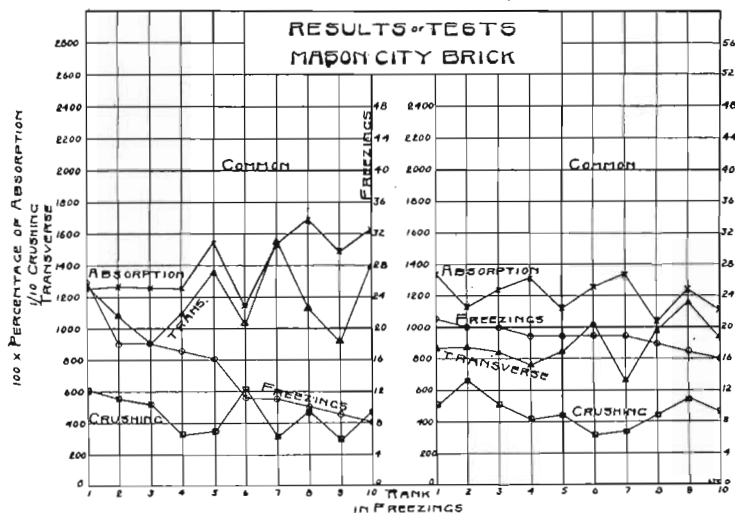


FIG. 105. Comprehensive diagram, Mason City brick.

The Ames brick were tested as representative of the old fashioned hand made, soft mud brick. The brick for the two sets of tests of Ames brick were selected from a pile delivered at a house near the college, as the yard is no longer operated. They probably represent about the best brick to be found in large percentage in the output of the yard.

RESULTS OF TRANSVERSE TESTS.

In figs. 90 to 93, inclusive, the results of the transverse tests are given. It should be clearly understood that in these diagrams, as well as in all which are to follow, it is the "modulus of rupture," i. e., the tensile stress in the outer fibre at breaking, which is shown, so that the size of the brick cuts no figure. The point of main interest in connection with figs. 90-93 is the comparison of the tensile strength of the brick when tested, first flatwise, as laid in a wall, and second, edgewise as laid in a pavement. The diagrams show no very material difference except in two instances, the Mason City common brick, and the Council Bluffs pavers. In the first of these exceptions the strength per square inch edgewise was the greater, while in the second case the strength per square inch flatwise was the greater.

In the case of the Mason City brick it is easy to see why the edgewise position should give the higher results, for in this the sound, extra good layers where the brick pressed against the die of the brick machine are put where they will do the most good, or farthest from the neutral axis. It will be remembered that the interior of these brick is badly fissured.

The Council Bluffs pavers were very hard burned, soft mud brick, and the defective side, the under side in the molds of the brick machine, was placed on top in the flatwise tests, where it would be in compression, and where the defects would have the least effect. The only difficulty in accepting this explanation for the flatwise modulus of rupture being the greater in this

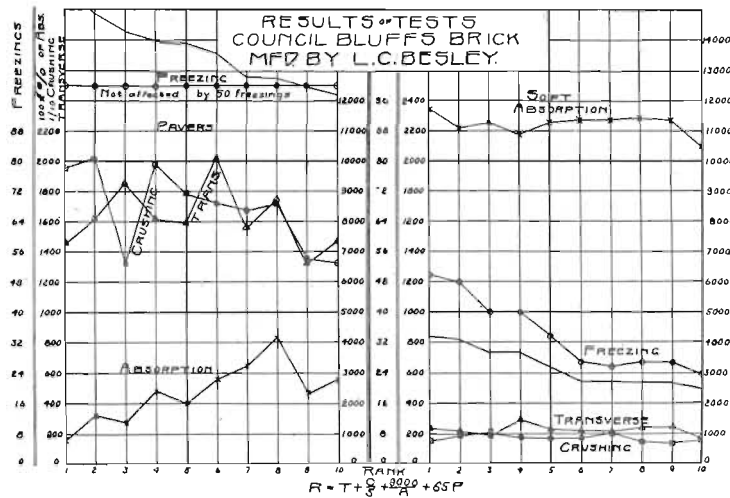


FIG. 103. Comprehensive diagram, Council Bluffs brick.

case is that we do not find the rule to hold true in the case of the soft Council Bluffs brick, nor in the case of the Ames hand made brick. Possibly the very hard burning of the Council Bluffs pavers made the defects, as would be the case with glass, very much more important as affecting the tensile strength.

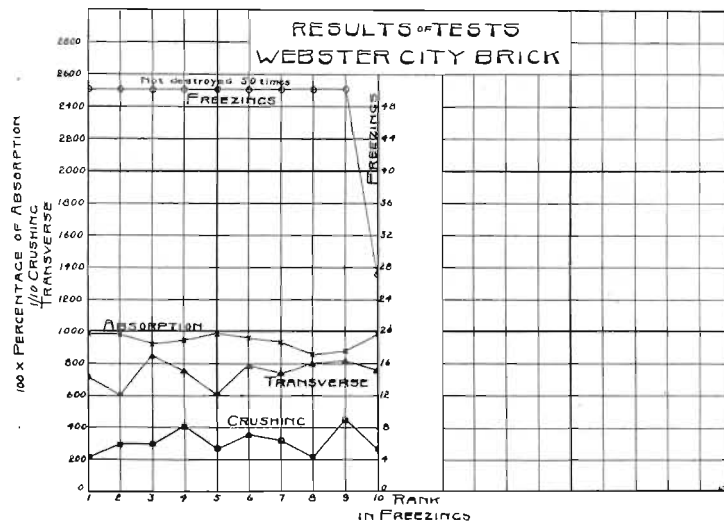


FIG. 107. Comprehensive diagram, Webster City brick.

From the results of these tests we may conclude that in transverse tests of common brick sometimes the edgewise and sometimes the flatwise position gives the greater modulus of rupture, depending on the structure of the brick, and that usually there is no very material difference.

In the diagrams which follow the modulus of rupture is from the flatwise tests.

RESULTS OF ABSORPTION TESTS.

In figs. 94 to 100, inclusive, the detailed results of the absorption tests are given. From these it is seen that when an inch cube of brick is immersed in water the absorption is at first very rapid. Within thirty minutes a large proportion of the total water eventually absorbed by the brick has been taken up. After this the rate of absorption proceeds at a continually diminishing rate until a period of from four or five up to thirty hours after the first immersion. After these initial periods a slow, steady, and very slowly decreasing additional absorption of water continues, which in nearly all the specimens was still going on after a lapse of two weeks.

Herein the brick are compared on the basis of forty-eight hours immersion. Although the final results would be ten per cent to fifty per cent greater, those for forty-eight hours were chosen because: first, the final per cents of absorption could not be obtained in any practicable test period; second, the forty-eight hours points on the absorption curves gave fair points for comparison, far enough removed from the starting points to be free from the irregularities where the curves bend rapidly; third, the water absorbed readily at first is of most importance, for brick are not usually so placed in structures as to become saturated with water, but they simply absorb part of what water is dashed against them by the storms.

As has already been indicated ten bricks were taken for each of the thirteen sets of tests made, and in each set of tests

each of the ten brick was subjected to each of the four tests, transverse strength, crushing strength, absorption, and freezing and thawing. In figs. 101-117, inclusive, the results of all these tests are shown. In further explanation it should be said that the transverse and crushing strengths are given in pounds per square inch, that the percentage of absorption is for forty-eight hours immersion of one inch, smooth cubes, and that the number of freezings platted is the number required to completely demolish a one-inch smooth cube saturated with water, the minimum freezing temperature being about two degrees above zero Fahrenheit.

RESULTS OF FREEZING TESTS.

The following should also be particularly noted in connection with the freezing tests. All ten of the Council Bluffs pavers remained practically unaffected at the end of fifty freezings,

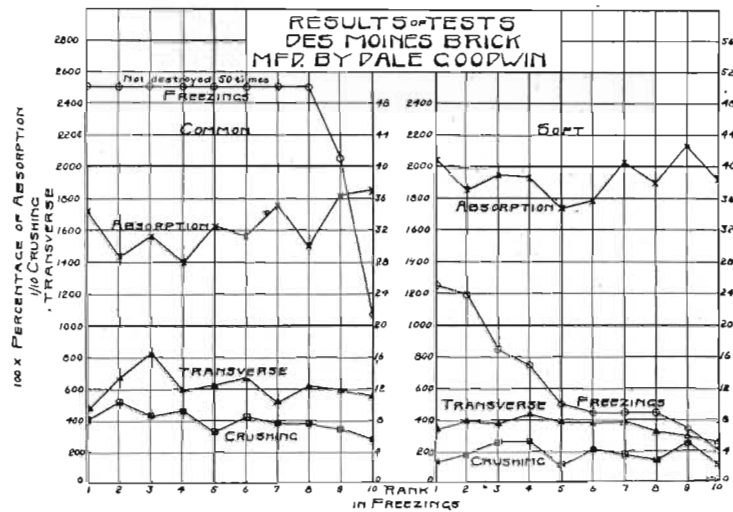


FIG. 108. Comprehensive diagram, Goodwin brick.

which was the number given all brick not demolished sooner. Of the Webster City specimens nine were not yet broken up and had lost only a small fraction of one per cent of their

original weights. Of the ten Dale common brick, six were not appreciably affected, one lost only 0.9 per cent and one 12.4 per cent. Of the ten Grand Junction brick, in the first set, one was very slightly affected, and two others lost respectively 0.8 per cent and 13.6 per cent. In the second ten, two were very little affected and three lost respectively 2.6 per cent, 6.3 per cent and 8.8 per cent. One of the surprising results of the tests described in this paper was that of the ten Kelly soft brick, three were not appreciably affected and one other was not demolished,

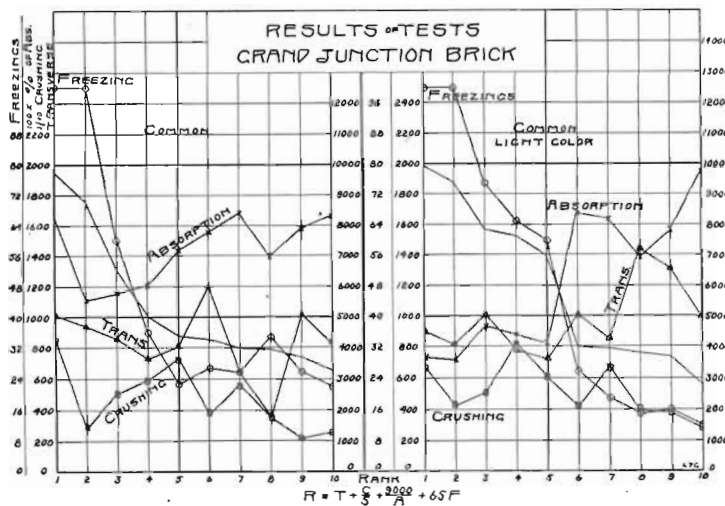


FIG. 108. Comprehensive diagram, Grand Junction brick.

though it lost 13.3 per cent of its weight. One of the second ten Ames hand made brick lost only 1.2 per cent.

In the diagrams those brick which were practically unaffected by fifty freezings were given an arbitrary rating of 100, and for the partially demolished cubes an approximate estimate was made of the number of additional freezings which would be required to totally demolish them. Of course this renders the absolute values platted for part of the freezing tests unreliable, but there is no uncertainty in the comparative results.

COMPARISON OF TESTS MADE.

In arranging all of these diagrams the aim kept in mind, in addition to showing the results in detail, was to so arrange the data that comparisons could be readily made between the results of the different kinds of tests. It was desired to ascertain conclusively whether the strongest brick would always have the lowest percentage of absorption, and especially whether it would always prove the most durable when exposed to freezing and thawing. In figs. 101 to 105, inclusive, the brick in each set of tests are arranged in the order of their resistance to freezing and thawing. In fig. 112 the average results for all ten brick of each set of tests are arranged in the order of transverse strength, and in fig. 113 in order of resistance to freezing and thawing.

By a careful study of the above diagrams some general correspondence between the results of the different tests can be traced, especially between the transverse, crushing and absorption tests, as evidenced by fig. 112, but this correspondence is only in a very general way and is subject to very many and very irregular exceptions. It is usually true that a very good brick will test better than a very poor brick in all four ways, as is seen by comparing the Council Bluffs pavers with the Council Bluffs soft, or the Dale common brick with the Dale soft, for example; but when different kinds of common brick are tested it very frequently happens that the stronger brick may not resist freezing so well as the weaker brick, and sometimes the weaker may also have a lower per cent of absorption.

To properly rank brick from the results of tests evidently requires some method which can properly take into account the results of all the tests. When we come to a consideration of this subject the question at once arises, what constitutes the value of a particular kind of brick? Obviously many things con-

tribute which are not subject to test, as, for example, regularity of form, smoothness of exterior, beauty of color, freedom from efflorescence. The qualities usually tested are strength, both transverse and crushing, and porosity. In this investigation the durability when exposed to freezing, has also been tested.

Of these three qualities strength is undoubtedly a very important quality, for a principal function of any wall is to carry weight, and the strength of a wall will depend upon the strength of the brick of which it is made. The transverse strength

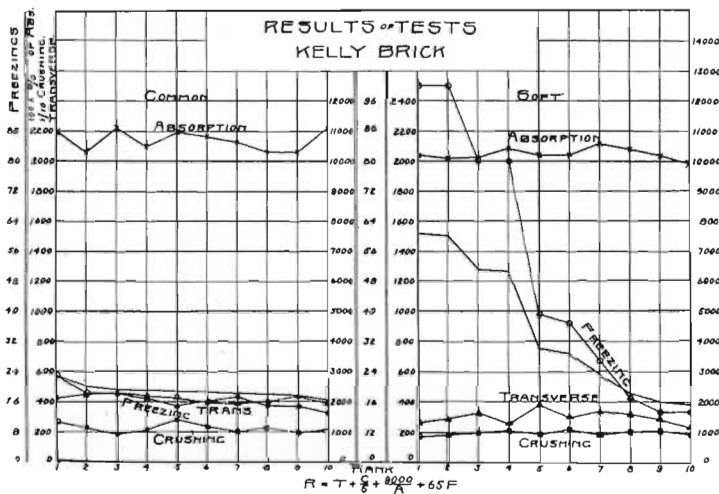


FIG. 110. Results of tests, Kelly brick.

as well as the crushing is of importance, for unsightly cracks due to uneven settlement are common and there is danger of cracks of individual brick due to imperfect bedding. The strength of the bond will also depend largely on the transverse strength of the brick.

The absorptive power of a brick is also important but not so much so as the strength. Upon the absorptive power must depend in a measure the liability to discoloration from dirt, and the more absorptive the brick the greater danger to the mortar from suction before it sets.

Undoubtedly for brick used in this climate the most important quality subject to test is the durability when exposed to freezing and thawing. It is seldom that walls fall by crushing under too great weight, while on the exterior of almost any building made of common brick a close search after a few years' exposure to our climate will disclose some evidences of disintegration.

The weight to be assigned to each of the qualities enumerated above will depend upon the use to which the brick are to be put. For example, in an interior pier not subjected to freezing at all but carrying a very heavy load, strength would be the all important quality. In other cases the resistance to freezing and thawing may be all important, and in fact is usually much more important than any other quality subjected to test. On the whole it seems fair to give strength twice the weight given to the results of the absorption test and to give the freezing and thawing test a weight equal to all of the other tests combined.

In order to prepare formulæ embodying this it is necessary to know what are the average ratios between the results of the different kinds of tests. For the brick tested in these experiments the results are shown in the following table:

TABLE SHOWING COMPARATIVE RESULTS OF BRICK TESTS.

Kind of Brick.	Transverse Strength lbs. per sq. in.	Crushing Strength lbs. per sq. in.	Per Cent Absorption	No. Freezings to Destroy 1" Cube	Ratio $\frac{C}{T}$	Product $T \times A$	Ratio $\frac{T}{F}$	$R = T + \frac{C}{5} + \frac{9000}{A} + 65F$	$R' = \frac{2T}{65F} + \frac{9000}{A}$
Council Bluffs Pavers	1620	16800	4.7	100	10.4	7600	16.2	13409	11700
Webster City Common	740	3060	9.5	90	4.1	7000	8.2	8100	8300
Dale Common	610	3000	15.4	81	6.4	9400	7.5	7200	7100
Grand Junction Lt. Col. Common	990	5180	12.3	40	5.2	12200	20.3	6000	5900
Grand Junction Common	840	4720	13.5	45½	5.6	11300	18.5	5400	5300
Grand Junction Average	910	4950	12.9	47	5.4	11700	19.4	5790	5600
Kelly Soft	300	1930	20.5	51	6.4	6200	5.9	4400	4300
Mason City Common.	890	4660	12.1	19	5.2	10800	47.0	3800	3800
Mason City Common	1170	4460	13.8	15	3.8	16100	78.0	3700	3000
Mason City Average.	1030	4560	13.0	17	4.5	13400	60.6	3700	3800
Council Bluffs Soft...	239	1790	22.6	34	7.8	5290	6.8	3200	3100
Ames Common	280	1510	22.7	31	5.4	6300	9.0	3000	3000
Ames Common	230	1470	21.8	27½	6.4	5000	8.4	2700	2700
Ames Common Average	250	1490	22.3	29	5.9	5600	8.6	2800	2800
Kelly Common	420	2240	21.4	17	5.3	9000	24.8	2400	2400
Dale Soft	360	1830	19.3	13	5.1	6900	27.8	2000	2000
Average 6 Common..	660	3370	15.7	47	5.3	9400	21.5		
Average 3 soft	300	1850	20.8	33	6.4	600	13.5		

It will be seen that some of these ratios are subject to wide fluctuations and the average values are not to be taken as yet well established by the results of this single series of tests.

RATING FORMULA.

For a rating formula whose coefficients are approximately determined, we may take, however,

$$R = T + \frac{C}{5} + \frac{9000}{A} + 65F,$$

In which R is a ranking number.

T—Transverse modulus of rupture in pounds per square inch.

C—Crushing strength in pounds per square inch.

A—Per cent of absorption in forty-eight hours immersion.

F—The number of freezings required to demolish a one-inch smooth cube.

In figs. 106 to 111, inclusive, the results of the individual tests are arranged according to this formula, and in the later diagrams the average results of each set of tests are arranged in similar manner. Of course the tests correspond much more nearly to the rank when arranged in this way than in figs. 101 to 105, for the results of the tests are taken into account in making the arrangement.

This subject is one which demands considerable further investigation.

Crushing tests are difficult and expensive. In case they have not been made the transverse strength may be given double weight, making the formula.

$$R' = 2T + \frac{9000}{A} + 65F,$$

In the above table the values of R' are also given and it will be seen that they rank its brick in the same order as R .

Attention is called to the results of the freezing test in the case of the Mason City brick and the Kelly brick. In the case of the Mason City brick it is undoubtedly true that the results of the freezing test did not correctly indicate the durability of the brick as they are commonly used in walls.

The structure of these brick has already been discussed and it will be remembered that the interior is considerably fissured, while the exterior surfaces which are exposed to the weather are smooth, dense and hard, and not fissured. In the freezing test the brick are saturated with water taken into the interior fissures, whereas when laid in a wall the brick could not absorb much water on account of the dense, hard exterior skin.

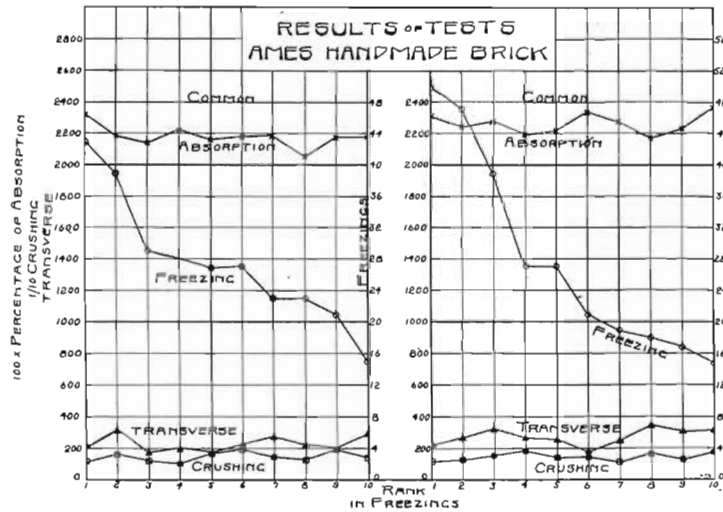


FIG. 111. Results of tests, Ames hand made brick.

In the case of the Kelly brick it was a very surprising thing that the soft brick tested better than the well burned brick as regards the per cent of absorption and especially as regards the resistance to freezing and thawing. It is very difficult to ex-

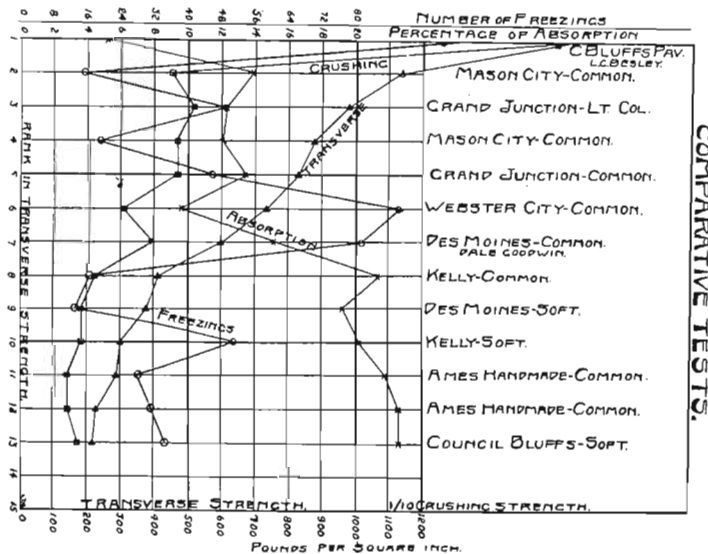


FIG. 112. Diagram showing comparative results of tests.

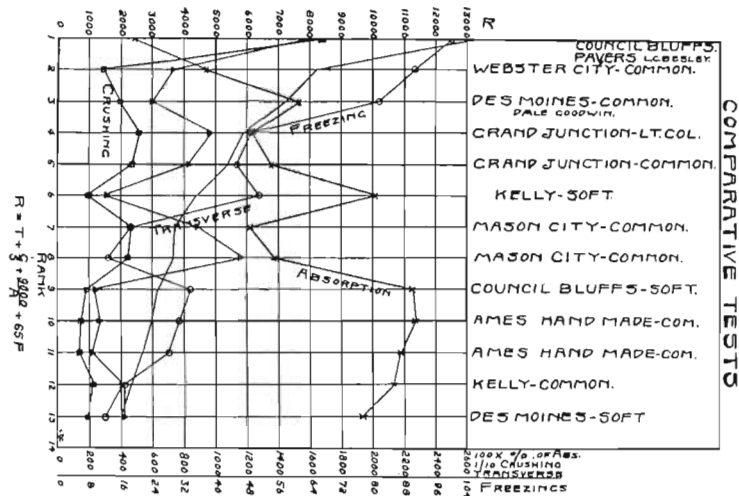


FIG. 113. Diagram of comparative results.

plain why this should be the case for the soft brick were pale and apparently not so well burned as the common brick. The only explanation which can be given by the author is perhaps that the clay of which the soft brick were made was taken from a different place in the pit and was of much better material than that from which the common brick were made. There is some in-

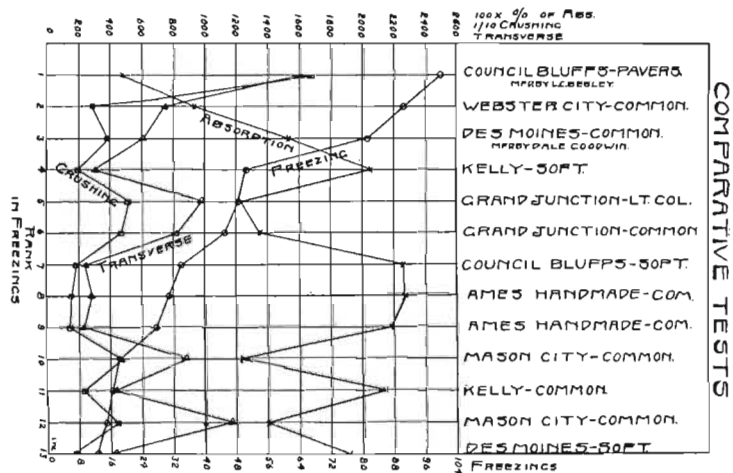


FIG. 114. Diagram of comparative results.

dication of this in the brick, for the common brick showed many more nodules of lime than the soft brick.

Tests of Strength of Hollow Building Blocks.

ADVANTAGES OF HOLLOW BLOCKS.

During the last few years there has been an extensive development in the manufacture and use of hollow clay blocks in place of solid brick for building construction. These blocks have some strong advantages in competition with brick. One is the saving in weight, which leads to economy where the material must be transported long distances. In the walls themselves the saving in weight may often be of great importance as it lessens the loads on the other parts of the building and on the foundations. Another very important advantage of hollow blocks is in the air space in the walls due to the hollow spaces in the blocks. These secure much drier walls. Another advantage is the larger size of the blocks, which permits greater rapidity in laying and makes a much smaller number of joints. Of course the greater disadvantage of brick masonry as compared with stone masonry is in the much larger number of joints imperfectly filled with mortar through which cold air may find its way.

However, hollow blocks have not been used a sufficient number of years to thoroughly demonstrate their merits and it often becomes difficult to secure their use. The principal objection which is raised to them is their lack of strength as compared with solid brick. There is no doubt that hollow blocks are much weaker than solid brick and that hollow block walls are much weaker than walls constructed of solid brick. This objection is so strongly urged that it sometimes prevents the use of hollow blocks in places where they would otherwise be adopted.

TESTS OF HOLLOW BLOCKS.

During the past few years several tests of the strength of hollow blocks have been made by the civil engineering department of the Iowa State College and for the information of manufacturers and users of building materials they are grouped in the table given below. All the tests were made by imbedding the building blocks in plaster of Paris in the 100,000 pounds testing machine of the engineering division at Ames. The blocks were imbedded in plaster of Paris both at the top and the bottom and the plaster of Paris was allowed to set usually over night. An adjustable top bearing was used to enable the machine to adjust itself to lack of parallelism of the top and bottom.

TABLE SHOWING TESTS OF IOWA HOLLOW BLOCKS.

MANUFACTURER.	Approximate dimensions	Position.	Crushing strength tons per square foot.
Capital City Brick and Pipe Co., Des Moines, Iowa.	4x8x12	Flatwise.	78.1+*
	4x8x12	Endwise.	230.8
	4x8x12	Edgewise	171.5+*
Mason City Brick and Tile Co., Mason City, Iowa.	4x8x12	Flatwise.	64.0
	4x8x12	Edgewise	59.6
	5x5x12	Flatwise.	39.1
	4x4x12	Flatwise.	56.5
Sioux City Brick and Tile Co., Sioux City, Iowa	5x8x12	Flatwise.	30.2
	5x8x12	Edgewise	65.0
Johnson Brothers, Kalo, Iowa	5x8x12	Flatwise.	47.0
	5x8x12	Endwise.	131.0
	5x8x12	Edgewise	59.9
Des Moines Clay Manufacturing Co., Des Moines, Ia	5x8x16	Flatwise.	49.0
	5x8x16	Flatwise.	55.5+*
	8x8x16	Flatwise.	58.0+*

* Failed to break at full power of testing machine.

In stating the results given in the above table it may be said that architects allow five to ten tons per square foot pressure

on brick masonry. Even if this usual pressure were adopted with hollow block walls a large factor of safety would evidently be secured. Of course in walls built of hollow blocks piers of solid brick are usually built to carry concentrated loads from beams and trusses. It may be said that with proper precaution the strength of hollow blocks appears ample for all ordinary building construction.

Tests of Iowa Paving Brick.

GENERAL CONSIDERATIONS.

The manufacture of paving brick constitutes a very important part of the manufacture of clay products in Iowa. Although the use of brick paving has been very extensive it began at a comparatively recent date, and the standardizing and developing of the various tests of the material is, even yet, in an unsatisfactory state. It cannot be said that the development of satisfactory tests has kept pace with the use of paving brick.

In Iowa the manufacture and use of paving brick developed very rapidly in the few years following 1890, but, owing largely to uncertainties regarding the constitutionality of paving laws, there has been a lull in the extension of brick paving until very recently. The construction of paving is now again developing, but the brick are coming into keen competition with asphalt. The question of brick paving versus asphalt paving is one which has aroused bitter discussions in several Iowa cities during the last year or two, and it must be admitted that the use of asphalt has greatly increased recently in this state. It is easy to see why this should be the case when consideration is given to the pleasing appearance, the smooth unbroken surface and the comparatively noiseless character of the asphalt paving.

ADVANTAGES OF BRICK PAVING.

It must be admitted that brick paving has many advantages as compared with asphalt or any other form of paving, especially in the middle west, and there is practically no doubt that the construction of brick pavements will continue to be more extensive in the future. In the first place, brick is cheaper than asphalt, and this is an important consideration, especially in the cities of Iowa which have yet to construct pavements. Second, as is proven by recent tests by the civil engineering department of the Iowa State College at Ames, and by other experimenters, the traction on brick pavements is materially less than on asphalt, contrary to the common impression due to the smooth surface of asphalt pavements. Third, brick pavements do not require so high a degree of professional skill for their repair and maintenance. It is an interesting question to consider what the smaller cities of Iowa which are putting in asphalt pavements at the present time will do when the guarantee period expires and they are thrown on their own resources, or the mercy of the large corporations to repair and maintain their pavements. Fourth, the methods of construction of good brick pavement and the materials and processes can be submitted to constant direct inspection and supervision, while with asphalt entire confidence must be placed in the contractor. Fifth, brick pavement is capable of withstanding successfully heavier traffic than the asphalt, although this statement should be qualified by the statement that asphalt is suited to much heavier traffic than it was formerly supposed it could successfully stand. Sixth, brick pavements are not so slippery as asphalt pavements and can be constructed on much steeper grades.

PAVING BRICK TESTS.

The above extensive list of advantages insures that the manufacture and use of paving brick will continue to be extensive and

important in the state of Iowa. Consequently, tests of the paving brick of the state are of great interest and value, if made sufficiently numerous and with sufficient skill and care. During the last four years the civil engineering department of the Iowa State College has been engaged in making an extensive series of tests of Iowa paving brick, in all over four thousand individual tests having been made. The calculation, compilation and discussion of these tests require a vast amount of labor, which has not yet been entirely completed, so that we are now able to give only a preliminary report of the tests. In the following diagrams the principal results of these tests may be seen in the most compact form possible.

The brick for these tests were furnished by the following manufacturing companies:

Capital City Brick and Pipe Company, Des Moines, Iowa.

Merrill Brick Company, Des Moines, Iowa.

Iowa Brick Company, Des Moines, Iowa.

Flint Brick Company, Des Moines, Iowa.

Granite Brick Company, Burlington, Iowa.

Boone Brick, Tile and Paving Company, Boone, Iowa.

Each of these companies was asked to furnish three kinds of brick: first, the best or No. 1 brick, which in these diagrams is designated by the subscript "A"; second, the overburned brick, which in these diagrams is designated by the subscript "B"; and third, the underburned or soft brick, which in these diagrams is designated by the subscript "C." In the diagrams, also, for the sake of avoiding a large amount of lettering the initial letter of the company's name is used to designate the brick. Hence the following is the key to the kinds of brick given on the diagrams:

Capital City Brick and Pipe Company,

No. 1 brick	C _A
Overburned brick.....	C _B
Soft brick	C _C

Merrill Brick Company,

No. 1 brick.....	M _A
Overburned brick	M _B
Soft brick.....	M _C

Iowa Brick Company,

No. 1 brick.....	I _A
Overburned brick.....	I _B
Soft brick	I _C

Flint Brick Company,

No. 1 brick	F _A
Overburned brick.....	F _B
Soft brick	F _C

Granite Brick Company, (Burlington)

No. 1 brick	Bu _A
Overburned brick	Bu _B
Soft brick.....	Bu _C

Boone Brick, Tile and Paving Company,

No. 1 brick	Bo _A
Overburned brick	Bo _B
Soft brick.....	Bo _C

An examination of the diagrams will show as a very striking fact the great lack of uniformity of the results of all paving brick tests. This same lack of uniformity is encountered by all careful experiments and is an indication of corresponding variations in the properties of the brick. It is evident, on account of this lack of uniformity, that a large number of tests should be made of each kind of brick to give results at all worthy of use.

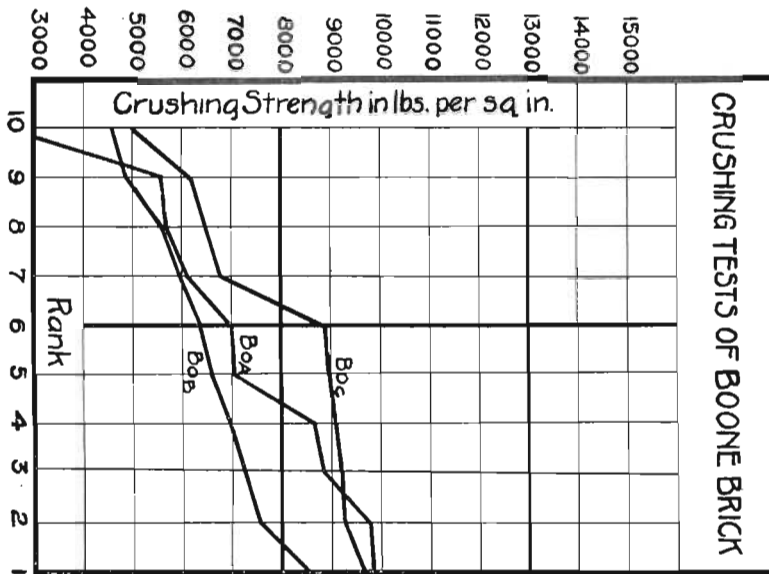


FIG. 115. Crushing tests, Boone brick.

The tests of paving brick which have been made in the past are four in number: the crushing test, the absorption test, the test of transverse strength and the rattler test.

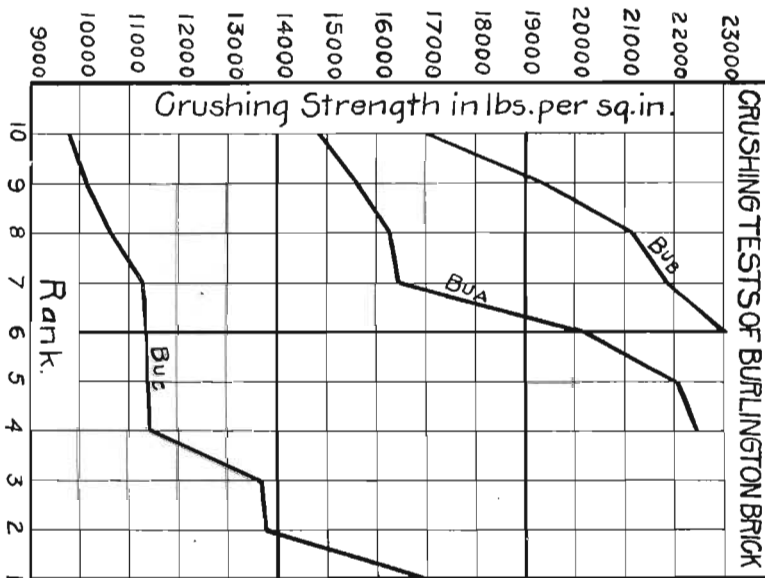


FIG. 118. Crushing tests, Burlington brick.

THE CRUSHING TEST.

The crushing test of paving brick may be said now to have been abandoned by practically all experimenters. In the inves-



FIG. 117. Crushing tests, Capital City brick.

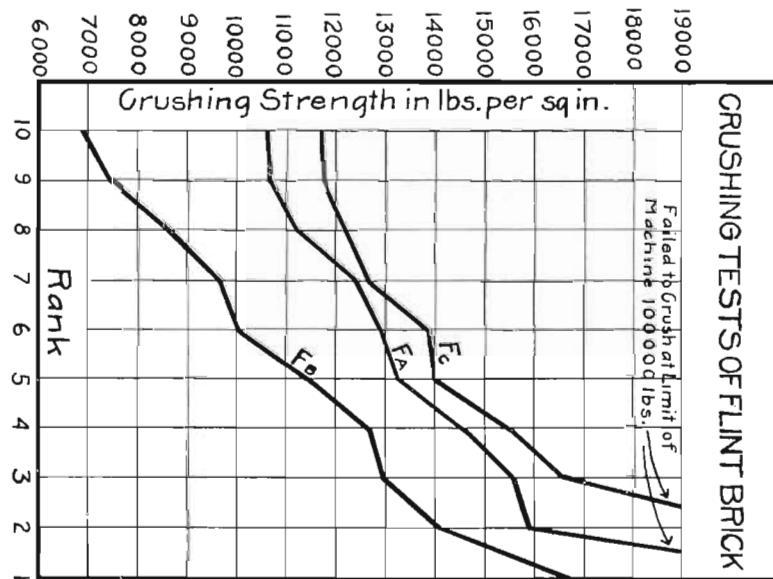


FIG. 118. Crushing tests of Flint brick.

tigation now under discussion crushing strength was determined simply as a matter of scientific interest. Paving brick never fail in the street by direct crushing and, in fact, the crushing strength of paving brick compares very favorably with the strength of granite. The test is not abandoned because its results would be of no value or interest, but because the same information can be secured by transverse tests in a much simpler and less expensive manner. The crushing test requires a very

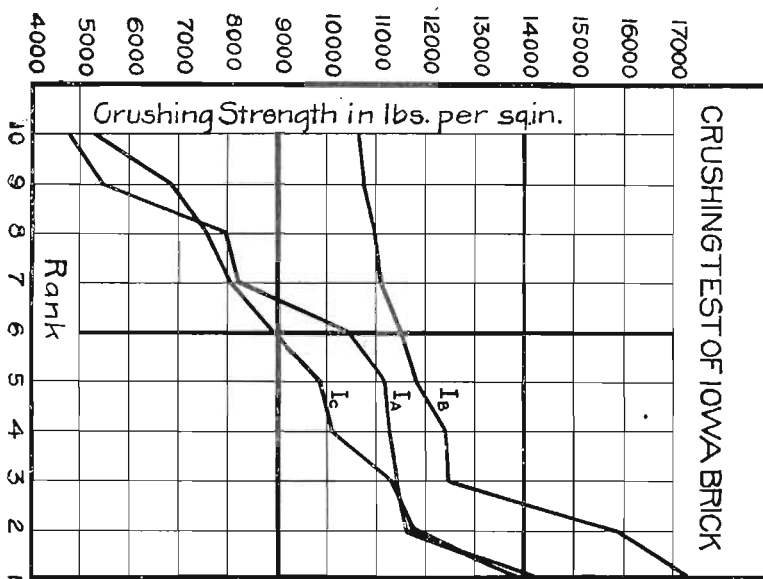


FIG. 19. Crushing tests of Iowa brick.

powerful testing machine and it is difficult and expensive to prepare the specimens for the tests. All the crushing tests in this investigation were made of ends of brick previously broken in the transverse tests. These were shaped so as to be practically square in cross section. The upper and lower edges of the brick were made respectively the upper and lower bearing surfaces in the tests. These bearing surfaces were carefully ground to true planes and in the testing machine were placed immediately

in contact with steel bearing plates. The upper bearing plate was adjustable to take care of lack of parallelism.

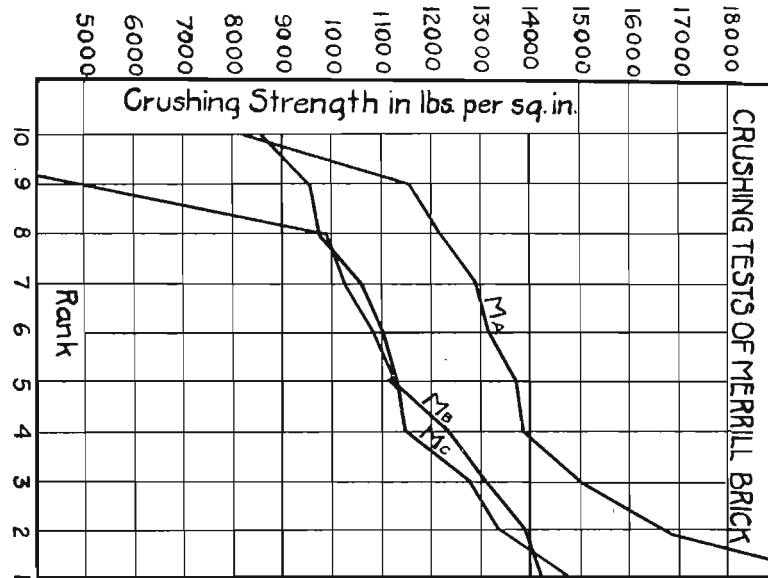


FIG. 120. Crushing tests of Merrill brick.

THE ABSORPTION TEST.

The absorption test of paving brick is of value as showing the hardness of burning of the material. However, when brick from different localities, made from different materials, are compared, the absorption test cannot be taken as a relative index of the quality, for some materials give a larger percentage than others of absorption for the same degree of vitrification. The absorption test has been standardized by the National Brick Manufacturers' Association, and these tests have been conducted in accordance with their recommendations. The tests are made of brick previously tested in the rattler tests so that the outer skin is removed. These are first placed in the oven and dried for forty-eight hours, then soaked in water and the per cent of gain in forty-eight hours determined. In the tests under discussion the bricks were weighed at intervals up to many days immersion.

THE TRANSVERSE TEST.

The writer considers the transverse test of paving brick to be one of the most valuable made, although he must confess that in this opinion he is not well supported by all other experimenters on paving brick. As a result of his experience in making thousands of tests, the writer, nevertheless, believes that the transverse test furnishes fully as reliable an index of the quality of

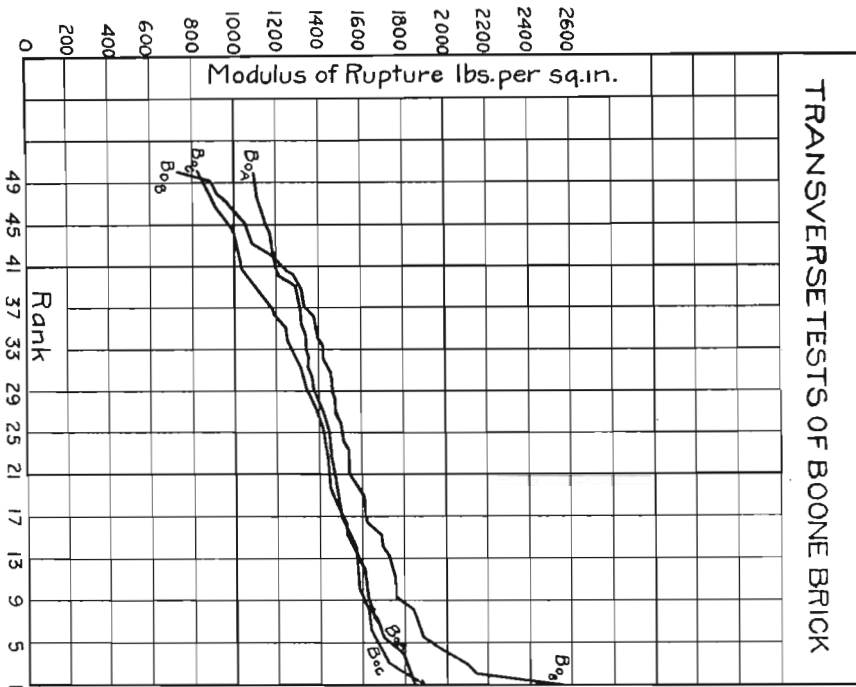


FIG. 121. Transverse tests of Boone brick.

paving brick as any yet proposed. In fact, in some cases under his observation, where the quality of the brick was known in other ways than by test, the writer has believed that the transverse test gave more accurate indications as to the relative quality of the brick than the rattler test. When we understand that actual use of brick in pavements has not always given results agreeing with the rattler tests of the material, and when we

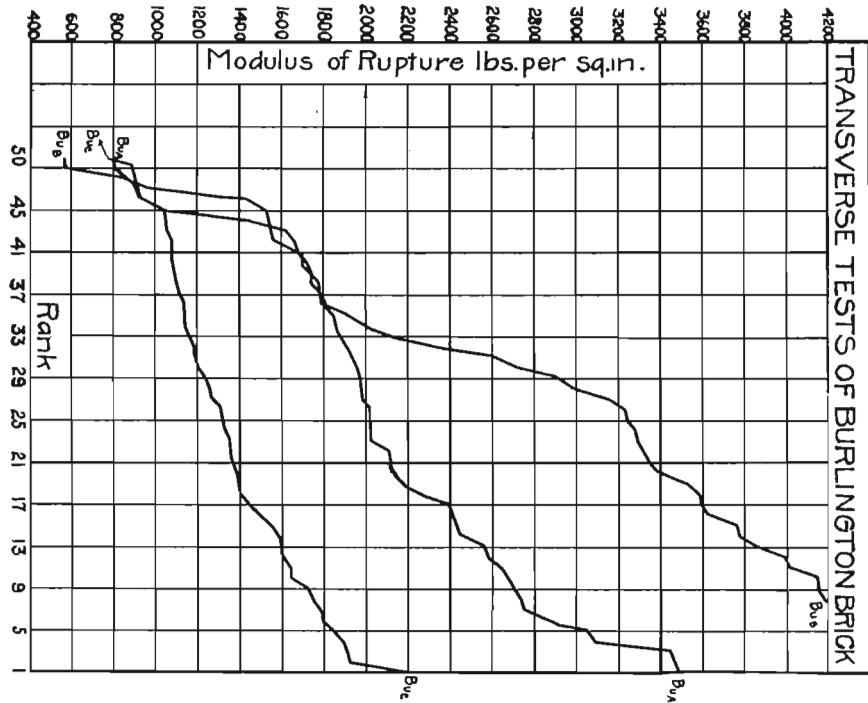


FIG. 122. Transverse tests of Burlington brick.

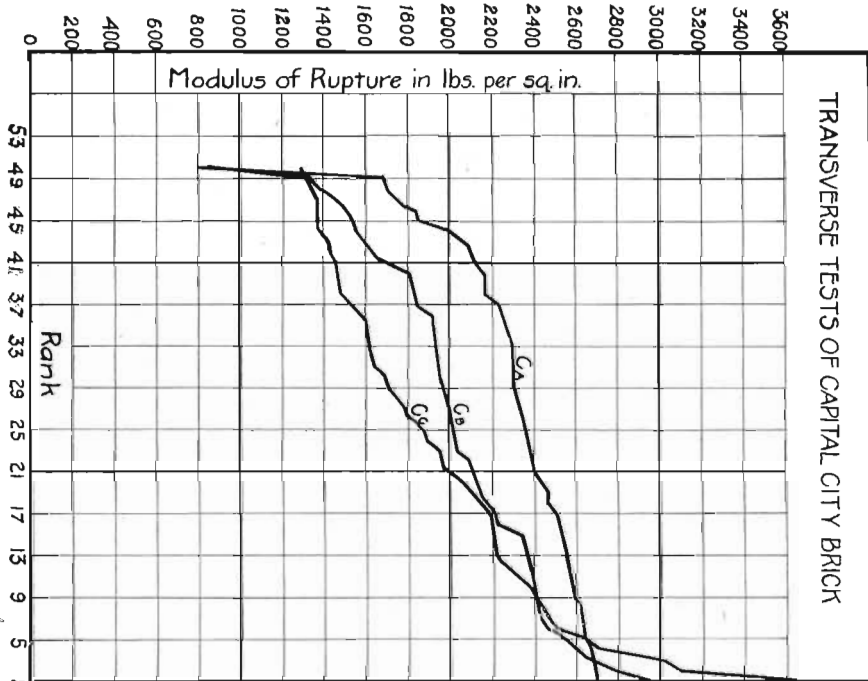


FIG. 123. Transverse tests of Capital City brick.

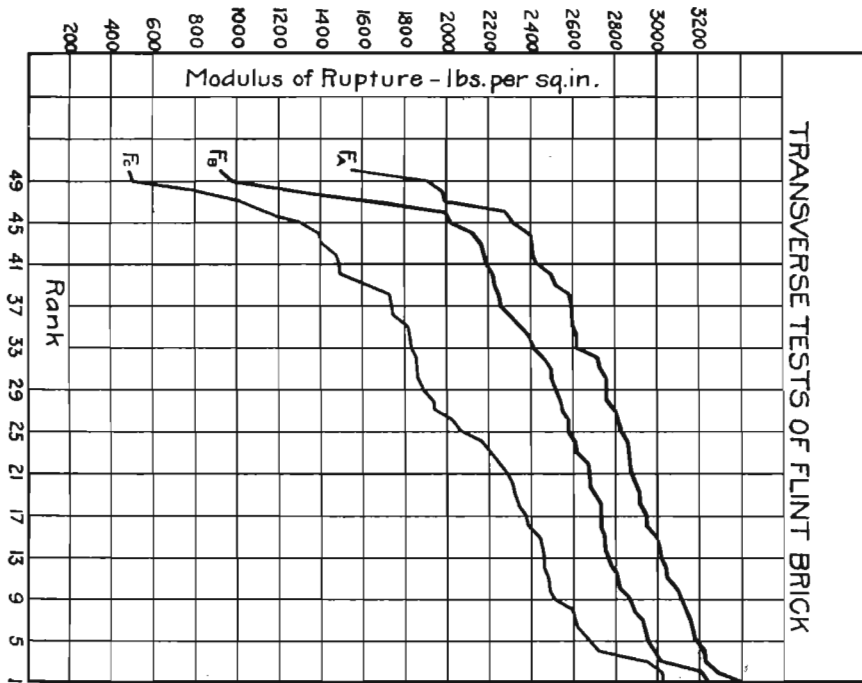


FIG. 124. Transverse tests of Flint brick.

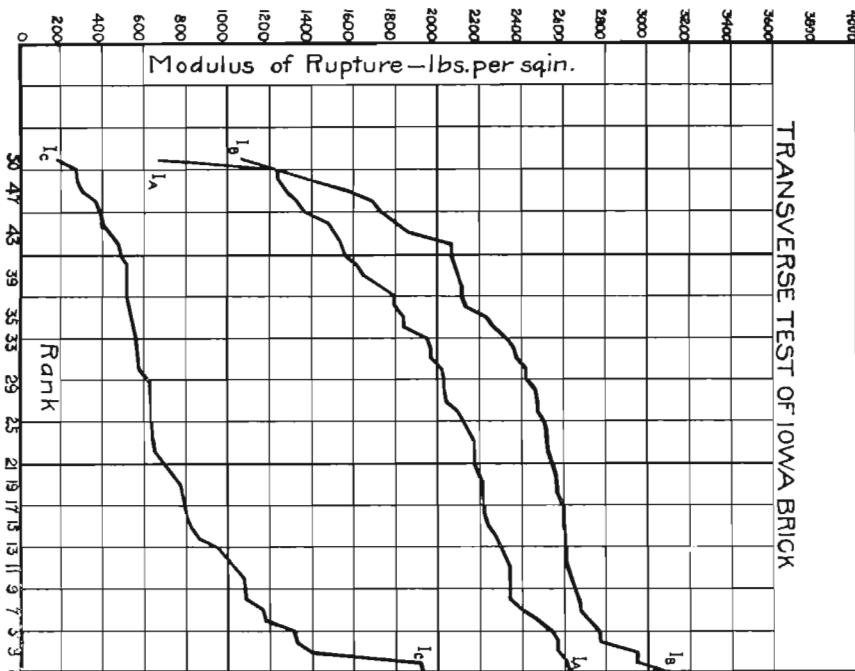


FIG. 125. Transverse tests of Iowa brick.

further have been embarrassed by the great diversity in the results of paving brick of apparently the same grade, we may well question the acceptance of the rattler tests as being infallible and of itself all-sufficient.

In the civil engineering laboratory at the Iowa State College the transverse test has been standardized in a somewhat different manner from that commonly followed by experimenters.

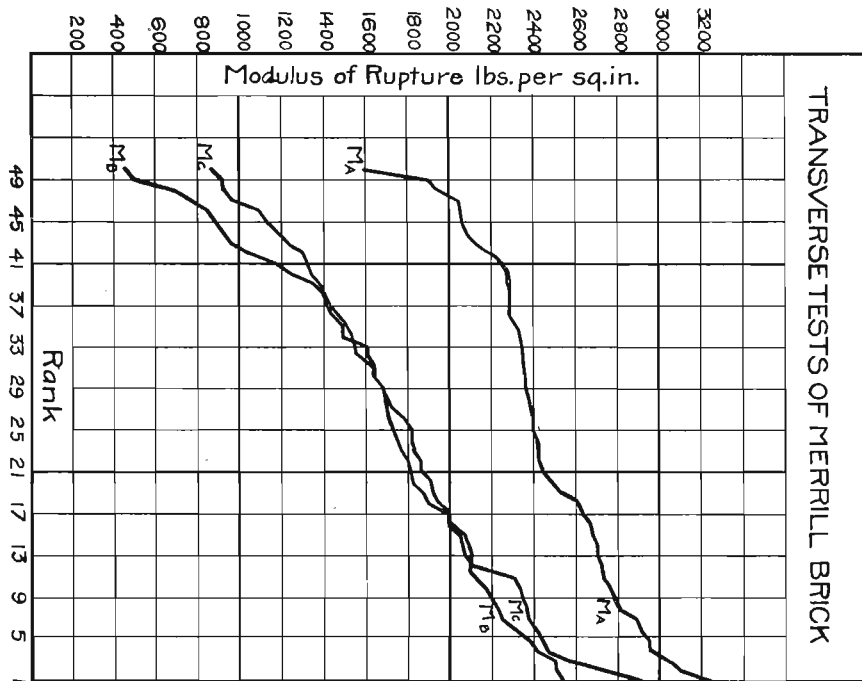


FIG. 123. Transverse tests of Merrill brick.

The brick are placed on edge, supported near each end on knife edges six inches apart rounded both ways, and the load is applied at the center by an adjustable knife edge. Between all knife edges and the brick steel bearing blocks are placed to prevent knife edges cutting into the brick.

One great advantage of the transverse test is that it fully exposes the interior structure of each brick tested and that it searches out any hidden flaws.

THE RATTLER TEST.

The rattler test of paving brick is a test not usually made of other materials of construction, but is a test which has been developed especially for this work. It has come to be considered universally the most reliable test of paving brick. In the street under actual conditions of wear brick fail mainly by abrasion from the blows of the horses' feet and the wheels of loaded vehicles. In the rattler test the brick pound against each other

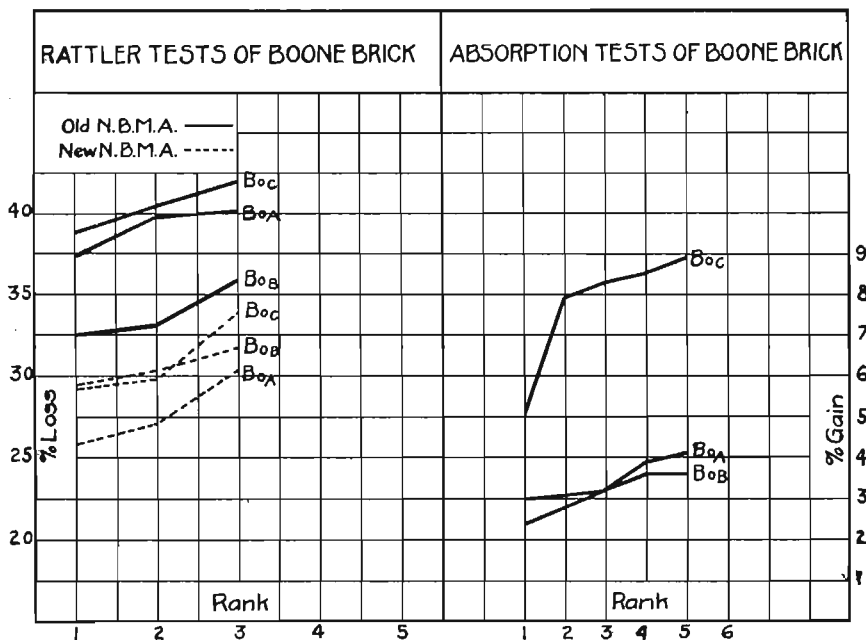


FIG. 127. Rattler and absorption tests of Boone brick.

and against the sides of the rattler, and the iron in the charge also pounds the brick in a way to produce excessive wear mainly by abrasion, and the brick fail in a manner somewhat the same as in actual use in the street.

A great deal of attention has been given to the standardizing of the rattler tests by the National Brick Manufacturers' Association, the work being done mainly by Professor Orton of the

Ohio State University. As a result of this work the National Brick Manufacturers' Association first recommended a standard method of conducting the test with the rattler containing only brick, and that these should be placed in to the extent of 15 per cent of the volume.

Experience with this method of testing soon lead to abandoning it and to the adoption of another method, which Professor

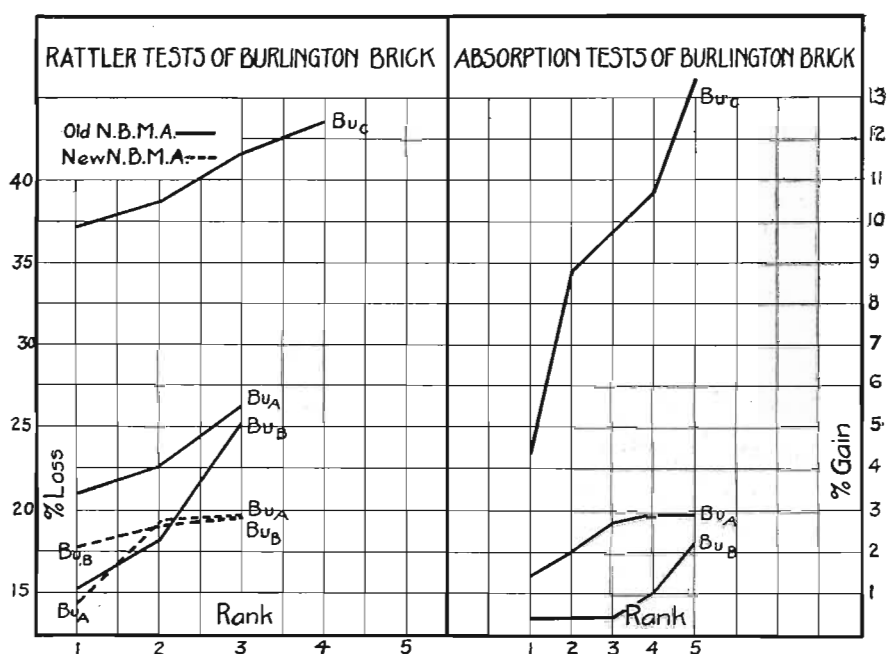


FIG. 123. Rattler and absorption tests of Burlington brick.

A. N. Talbot of the University of Illinois took a prominent part in developing. In the diagrams given herewith the method first proposed by the N. B. M. A. is designated as the "old N. B. M. A. test" and the new method as the "new N. B. M. A. test." The change was made while this investigation was under way.

Still another method of conducting the rattler test has been proposed, in which the brick are clamped around the interior perimeter of the rattler so as to make a sort of cylindrical brick

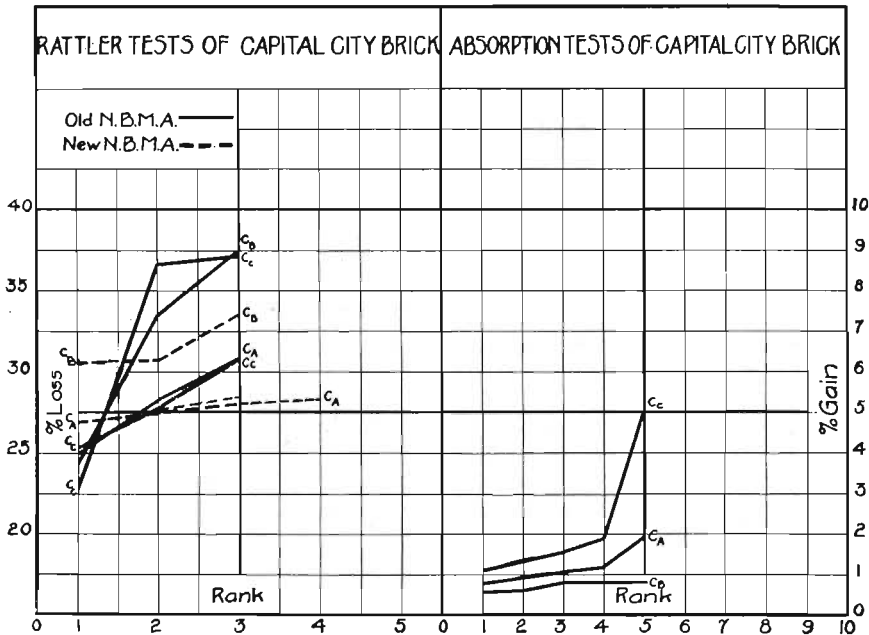


FIG. 129. Rattler and absorption tests of Capital City brick.

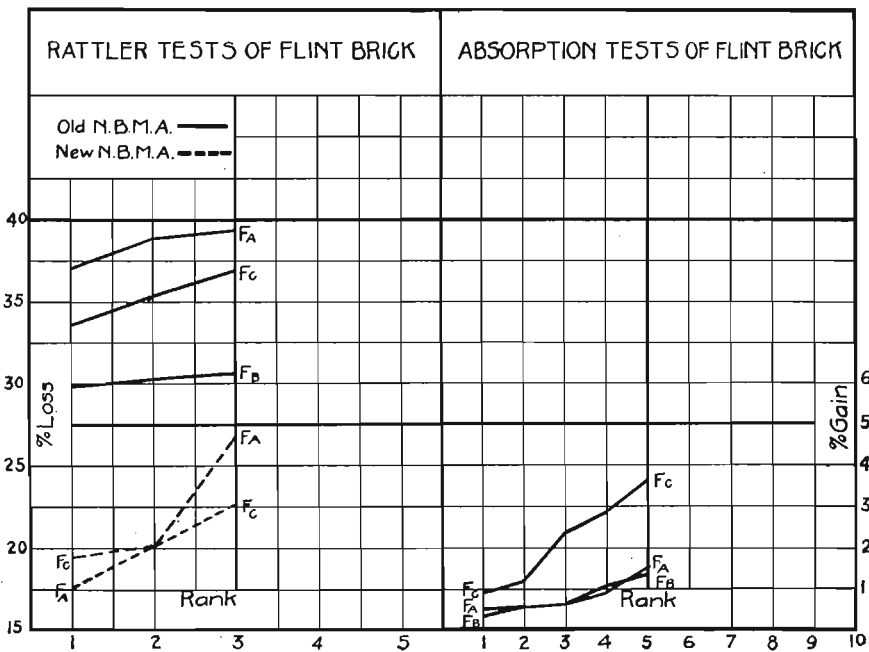


FIG. 130. Rattler and absorption tests of Flint brick.

pavement. The charge of iron in the machine then wears against only one edge of the brick in a way more closely resembling the wear in the street. In 1901 a commission of engineers consisting of the late Professor J. B. Johnson, dean of the college of engineering of the University of Wisconsin, Professor A. N. Talbot of the University of Illinois, Professor W. K. Hatt of Purdue University, and Professor A. Marston of Iowa

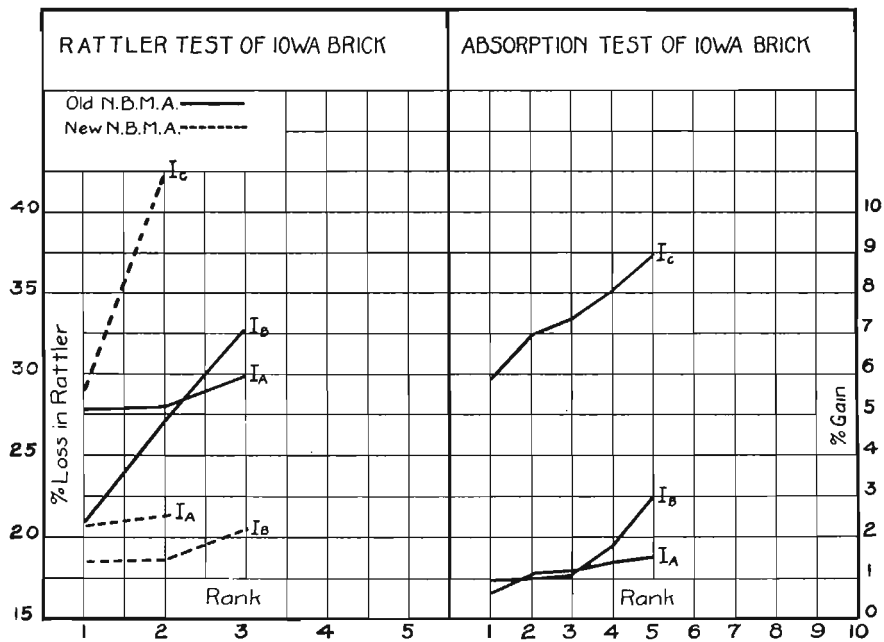


FIG. 131. Rattler and absorption tests of Iowa brick.

State College, met Professor Orton and a number of brick manufacturers, and other people interested in paving brick tests at Columbus, Ohio, to report upon the advisability of adopting this other method of testing. After careful consideration of the extensive series of tests reported, this commission advised against the adoption of the proposed method and recommended adherence to the old method, called in this paper the "new N. B. M. A. test."

It is very desirable that a standard method of conducting the rattler test should be adopted universally and it is strongly recommended that all rattler tests should be conducted in accordance with the following specifications, which have been adopted as standard by the National Brick Manufacturers' Association:

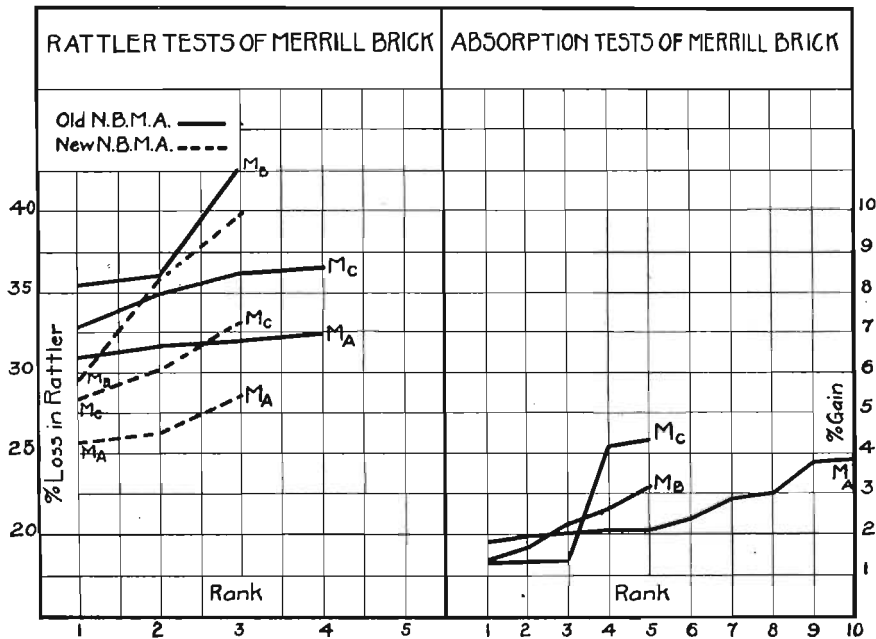


FIG. 192. Rattler and absorption tests of Merrill brick.

SPECIFICATIONS FOR STANDARD METHOD OF CONDUCTING RATTLER TESTS.

1. *Dimensions of Machine.*—The standard machine shall be 28 inches in diameter and 20 inches in length, measured inside the rattling chamber.

Other machines may be used, varying in diameter between 26 and 30 inches, and in length from 18 to 24 inches, but if this is done, a record must be attached to the official report. Long rattlers must be cut up into sections of suitable length by the insertion of an iron diaphragm at the proper point.

2. *Construction of the Machine.*—The barrel may be driven by trunnions at one or both ends, or by rollers underneath, but in no case shall a shaft pass through the rattler chamber. The cross-section of the barrel shall be a regular polygon, having fourteen sides. The heads shall be composed of gray cast-iron, not chilled nor case-hardened. The staves shall preferably be composed of steel plates, as cast-iron peans and ultimately breaks under the wearing action on the inside. There shall be a space of one-fourth of an inch between the staves for the escape of the dust and small pieces of waste.

Other machines may be used having from twelve to sixteen staves, with openings from one-eighth to three-eighths of an inch between staves, but if this is done a record of it must be attached to the official report of the test.

3. *Composition of the Charges.*—All tests must be executed on charges containing but one make of paving material at a time. The charge shall be composed of the brick to be tested and iron abrasive material. The brick charge shall consist of that number of whole bricks or blocks, whose combined volume most nearly amounts to 1,000 cubic inches, or 8 per cent of the cubic contents of the rattling chamber. (Nine, ten or eleven are the number required for the ordinary sizes on the market.) The abrasive charge shall consist of 300 pounds of shot made of ordinary machinery cast-iron. This shot shall be of two sizes, as described below and the shot charge shall be composed of one-fourth (75 pounds) of the larger size and three-fourths (225 pounds) of the smaller size.

4. *Size of the Shot.*—The larger size shall weigh about $7\frac{1}{2}$ pounds and be about $2\frac{1}{2}$ inches square and $4\frac{1}{2}$ inches long, with slightly rounded edges. The smaller size shall be $1\frac{1}{2}$ -inch cubes, weighing about seven-eighths of a pound each, with square corners and edges. The individual shot shall be replaced by new ones when they have lost one-tenth of their original weight.

5. *Revolutions of the Charge.*—The number of revolutions of the standard test shall be 1,800, and the speed of rotation shall not fall below 28 nor exceed 30 per minute. The belt power shall be sufficient to rotate the rattler at the same speed, whether charged or empty.

6. *Condition of the Charge.*—The bricks composing the charge shall be thoroughly dried before making the test.

7. *The Calculation of the Results.*—The loss shall be calculated in percentages of the weight of the dry brick composing the charge, and no result shall be considered as official unless it is the average of two distinct and complete tests, made on separate charges of brick.

While the rattler tests of Iowa paving brick are clearly shown by the diagrams given in this article, yet for the purpose of preparing specifications it is desirable that the numerical values should be available. These are presented in the following table.

In this table some rattler tests of the Purington paving brick, manufactured at Galesburg, Illinois, are also given for the purpose of comparison, because these Purington brick are so extensively used for pavements. Unfortunately we are unable to say that the Iowa brick make a better showing than the Purington brick, but it may be stated without fear of contradiction that the best grades of Iowa paving brick, as manufactured in enormous quantities at Des Moines during many years past, have demonstrated their good quality and reliability when used in brick pavements.

RATTLER TESTS OF IOWA PAVING BRICK.

PER CENT. OF LOSSES IN WEIGHT.

KIND OF BRICK.	GRADE OF BRICK.					
	No. 1.		Overburned.		Underburned.	
	Recommend- ed test.	Old N. B. M. A. test.	Recommend- ed test.	Old N. B. M. A. test.	Recommend- ed test.	Old N. B. M. A. test.
Flint, Des Moines.....	17.6 20.1 26.8	39.1 37.0 38.9	37.0 33.2 29.8 30.3	30.6 38.1 31.9	22.7 20.1 19.5	33.5 35.3 36.9
Average.....	21.5	38.3	32.5	33.3	20.8	35.2
Iowa, Des Moines.....	27.5 21.3 20.7	27.9 29.8 28.0	18.5 18.7 20.5	32.8 27.1 20.9	28.8 42.1	36.9
Average.....	23.1	28.5	19.2	26.9	35.5	36.9
Capital City, Des Moines.....	26.9 28.3 28.1	28.3 30.8 24.9	30.7 33.5 30.5	37.5 20.9 24.3 33.5	27.8 25.2 30.9	37.2 36.6 22.7
Average.....	27.7	28.0	31.6	29.0	27.9	32.2
Merrill, Des Moines.....	28.5 25.6 26.2	32.3 31.7 31.0 32.0	36.5 33.9 39.3	42.7 36.0 35.5	33.2 30.1 28.4	32.9 34.9 36.2 36.5
Average.....	26.7	32.3	36.6	38.0	30.6	35.1
Burlington.....	19.7 14.4 19.3	26.3 21.0 27.6	17.6 19.3 29.1	18.1 25.3 15.3	34.7	37.2 38.8 43.6 41.7
Average.....	17.8	25.0	18.6	19.6	34.7	40.3
Boone.....	30.3 28.8 27.2	39.8 37.4 74.2	31.7 30.3 29.5	35.9 32.5 33.1	29.8 29.2 33.6	40.4 38.7 41.9
Average.....	28.7	39.1	30.5	33.8	30.9	40.3
Purinton Paving Brick, Galesburg, Illinois.....	..... ..... ..... .....	17.8 18.9 19.0 20.3 .....	..... ..... ..... .....	19.0 20.1 22.0 .....	..... ..... ..... .....	16.3 22.8 30.6
Average.....	.....	19.0	.....	20.4	.....	23.2